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13th

ONTARIO INDUSTRIAL WASTE CONFERENCE

Proceedings

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THE

ONTARIO WATER RESOURCES COMMISSION

13th

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INDUSTRIAL WASTE

CONFERENCE

JUNE 19 - 22, 1966

PARK MOTOR HOTEL

NIAGARA FALLS

ONTARIO

PREFACE

D. S. Caverly,
General Manager,
Ontario Water Resources Commission,
Toronto.

Conference Chairman

The Park Motor Hotel in Niagara Falls housed the 1966 Industrial Waste Conference which was a fine success in terms of the attendance and the program. This was largely due to those who presented papers and the appreciation of this Commission is extended to them.

1966 saw the largest attendance at these meetings to date and we hope to surpass that next year. We will be meeting again in Niagara Falls at the Park Motor Hotel and it is hoped that many more people will attend these valuable sessions and actively participate.

It is gratifying to note the support of these conferences particularly since problems associated with the treatment of industrial wastes are receiving considerable attention and are of continuing concern. The Ontario Water Resources Commission is charged with the responsibility for pollution control in Ontario and hopes that by promoting the fullest co-operation among all, a better understanding of the many complex problems will be achieved. The maintenance of clean water in Ontario is a primary aim and through meetings of this nature the objective might be achieved.

For further information concerning the Industrial Waste Conferences or the activities of the Ontario Water Resources Commission you are invited to write to our offices at 801 Bay Street, Toronto 5, Ontario.

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"ASPECTS OF TANNERY WASTE TREATMENT"

BY

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CHEMICAL ENGINEER

In the time of ancient Greece, without fear of pollution problems downstream, Hercules could reroute a river through the Augean stables to remove in one day the manure which 3,000 heads of cattle had deposited there in 30 years. Times have changed radically since then, and water conservation and pollution prevention beset today not only the sanitary engineer but everybody from the top echelon of Government down to the broad masses of water users, and not only on our continent but in many areas all over the world. While modern technology has found procedures and installations to handle domestic sanitary waste in a satisfactory manner, industrial effluents in many instances still present serious problems.

Tannery waste, for a number of reasons, has been and still is a problem child of waste treatment. In order to discuss the many factors involved in the handling of tannery waste, it is necessary to understand that the numerous plants producing leather have one aspect in common: they are as different from

each other as the types of leathers which they manufacture. Even two tanneries making the same type of leather - like side leather for show uppers - can be quite different in their processes and consequently produce effluents of different composition and behaviour. To simplify our discussion of tannery waste treatment, we are going to limit ourselves to the two main groups of tanning processes:

> The mineral tannage typified by the use of trivalent chromium salts as tanning agent.
>
> The vegetable tannage which is characterized by using extracts of plants, taken from the wood, the bark or the fruits.

The tannery receives the hides or skins in either a salted or brined condition. The first operation in the tanning process consists in soaking the rawstock to remove salt, soluble proteins and dirt, particularly manure, and to allow the hide fibre to pick up again the moisture which it had lost during the curing process. The soaking process is followed by an unhairing process which removes the hair from the animal skin or hide, but this operation may vary. In some cases, the process of hair removal is conducted more gently in order to maintain the natural strength and character of the hair, in short to save the hair. In other cases, the hair is chemically decomposed, pulped or burnt, as the tanner calls it.

The unhairing process, in both instances, makes use of hydrated lime far in excess of the amount necessary to produce a saturated lime solution. The quantity of lime may vary from 4 to 10% of the green salted hide weight. The lime bath is sharpened by adding sodium sulphide or sulphydrate in small quantities in the hair-saving process, in larger amounts in the hair-burning process. Therefore, the discharge of the beamhouse, which is the department where the soaking and unhairing is performed, contains sodium chloride, lime slurry, sulphides, and organic matter from manure, proteins and keratines, forming together with the wash waters an effluent of high alkalinity and high BOD.

Speaking of BOD, one is too often inclined to consider the 5-day BOD value as a figure of comparison between sewages of different nature. One should keep in mind that the 5-day BOD result takes only one point out of a biodegradation process which had started 5 days before and has by no means reached an endpoint after 5 days reaction time. (Figure 1) In a "Study of Tannery Waste" [1] I have called attention to the importance of determining the progress of the BOD during the 5 days by testing identical specimens after 1, 2, 3, 4, and 5 days to obtain a picture of the variance in speed of biodegradability of industrial wastes. There is a marked difference between the composite raw waste of a chrome and of a vegetable tannery.

The chrome tanning process starts with the deliming of the dehaired hide to reduce the alkalinity of the pelt. Generally, in the same operation an enzyme is used to prepare the fibre for the subsequent tanning process. The next step is the pickle, a milling of the pelt in a sodium chloride solution of approx. 6 - 10 % concentration, acidified with sulphuric acid. The resulting bath has a pH of 2.0 - 2.5. Depending on the procedure used in the tannery, none, part, or all of the pickle may be discarded after usage. The tanning liquor, which is a concentrated, basified solution of chromium sulphate, is added to the tanning vessel, usually a rotating large drum of 8' to 10' diameter and 6' to 10' stave length. Upon completion of the tannage, the remaining float is drained. The effluent from the tannage contains sodium chloride, sodium sulphate, chromium sulphate, and some hide fibre; the pH varies from 3.5 to 4.0.

The chrome tanned leather, after some mechanical operations, is returned to a rotating drum for additional tanning operations, the so-called retan, and for colouring and fat liquoring. The retan may consist of applications of more chrome salt, vegetable extract, or synthetic tanning agents. Since all these materials are fairly well taken up by the leather, very little of these products go into the effluent. The colouring with aniline dyestuffs combines almost completely with the leather as do the fat emulsions used to provide the lubrication for the finished product.

The vegetable tanning process which nowadays applies mainly to sole leather making, is usually preceeded by a hair saving beam-house operation. Subsequently, the hides are suspended in a series of vats where they are treated with tan liquors of increasing strength. The tanner follows a counter-flow principle by hanging the pelt coming from the beamhouse into the vat containing the weakest tanning solution to exhaust as much of the tanning material as the hide will take during the time it stays in the vat, usually over night. The following day part of the vat content is discarded into the sewer and the vat volume is replenished from the following stronger vat for the next pack of hides.

In the case of sole leather tanning, normally a bleaching process is used after the tannage has been completed. First, the leather is dipped into a strongly alkaline bath to strip it of excess tanning material in the outer layer. Next follows a dip in strong acid to neutralize the alkalinity of the leather. Vegetable tanning material is characterized by its colour and acts like indicators, intensifying the red with increasing alkalinity, turning towards yellow in the acid range. This explains the reddish discolouration of the effluent from vegetable tanneries resulting from the mixing of the tan liquor waste with the highly alkaline beamhouse effluent.

This very brief resumé of the chrome and vegetable tanning processes by no means does justice to the many variations within the same process or to the combinations possible between the two systems. However, for our discussion of the aspects of tannery waste treatment it will suffice to recognize the three fundamental components we will encounter and with which we shall have to deal.

1. Beamhouse effluent of high alkalinity, pH around 11, consisting predominately of sodium chloride, lime slurry, alkali sulphides and solubilized proteins and keratines, accompanied by settleable solids in form of manure, fleshing particles, hair or hair pulp.

2. Chrome tanning effluent of acid character with a pH ranging from 2.0 - 2.5 of discarded pickle to 3.5 - 4.0 of exhausted tan liquor, consisting of sodium chloride, sodium sulphate, trivalent chromium salts and comparatively little organic matter.

3. Vegetable tanning effluent of moderately acid character with a pH of 4.5 - 5.5 in the discarded initial tan liquors and strongly alkaline and acid wastes respectively in the bleaching solutions. All these wastes contain vegetable tanning material of more or less intensive colour and with a high BOD.

How have tanneries been dealing with their effluent up to now? Some tanneries, located in large metropolitan areas have had the good fortune-though not always free of problems-to discharge all their waste into the community sewer lines for treatment in the city disposal plant. Where the ratio of sanitary waste to tannery waste is high enough to provide sufficient dilution, the tannery effluent is usually handled in a satisfactory fashion. The tanner pays for the service on the basis of the volume discharged; sometimes, where a town's ordinance has set specific limits, a surcharge for excess BOD and for solids is added.

Waste disposal becomes more problematic for the tanneries which have to provide their own treatment facilities and which in the majority of cases are located in or near small communities. In the past, retention and sedimentation ponds were provided and, with sensible operation and sufficient land available, were satisfactory. Draining of these ponds during high water flow in the receiving stream was an accepted practice. In this way the tanner could rid himself of the large quantities of sludge which accumulated in these retention basins regardless of whether the beamhouse effluent was kept in separate ponds or combined with the other tannery wastes.

With the more and more intensified "Clean Stream" programs, the tanneries have had to think of better ways to deal with their effluent problem. It is not surprising that higher density of industry and more intensely populated areas along the less numerous public waters in Europe brought about more advanced technical progress in the handling of industrial wastes, in particular in the treatment of the so obnoxious tannery effluent. During the past 15 years, my associate Dr. Herbert G. Scholz [2)] has made numerous installations for tanneries and other similar industries. He has progressively made improvements on the technical implementation of the process without changing the principles of the process.

Let us first consider the effluent of a chrome tannery (Figure 2). The wastes of the various departments, beamhouse, tanning room and colouring room are collected during the operating hours of the plant in an equalization tank of sufficient capacity to carry the effluent over the peak hours. The tank is equipped with a rotating bridge carrying an agitator and bottom rake which provides good mixing and prevents sedimentation in this tank. A pump is continuously drawing effluent from the equalization tank at a uniform hourly rate of approximately 1/20 of the daily load to deliver it to the chemical treatment, to sedimentation, and to final discharge. The purpose of the chemical treatment is to reduce the alkalinity, to remove the toxic sulphides, and to floc the colloidal protein decomposition products. In schematic A ferrous sulphate is used in the first step to precipitate the sulphides and to neutralize part of the alkalinity. The second step makes use of flue gas from the plant's boiler. A tank filled with iron shavings is sprayed from the top with some of the final effluent while from the bottom flue gas is blown into the tank. Ferrous bicarbonate is formed, drips through the perforation of the bottom into a collecting pan from where it flows at a rated discharge into the plant effluent. The result of the chemical treatment is neutralization of the alkalinity, conversion of the hydrated lime slurry into crystallized calcium carbonate, and precipitation of the solubilized proteins which are stabilized in the solution at the high pH but floc when the effluent is neutralized below pH 9. The treated effluent goes to the sedimentation unit from where the supernatant is discharged into the river and the sludge is pumped to the drying beds. In schematic B, the flue gas tower has been replaced by a tank equipped with an agitator of a Kessener brush type. The effluent, pretreated with ferrous sulphate, is mixed with air. The purpose is to oxidize the ferrous sulphide and to reduce the BOD of the effluent.

Schematic C represents the latest development in flue gas treatment. The effluent is pumped at a uniform hourly rate through the flue gas exchanger, a steel tank of appropriate capacity equipped with an agitator to mix the effluent with the flue gas. The gas is drawn from the boiler house stack through the flue gas exchanger and the exhaust gas is returned into the stack. The flue gas contains carbon dioxide and sulphur dioxide. The carbon dioxide neutralizes the effluent by converting the calcium hydroxide into calcium carbonate. However, the pH is lowered to around 8, enough to floc the colloidal proteins. The sulphur dioxide reduces the sulphides removing thus the toxic component from the effluent.

The installation of such a chemical treatment (Figure 3) becomes simpler and less costly wherever it is possible to separate the alkaline beamhouse waste from the tanning waste. The equalization tank can be of much smaller dimensions and so can be the flue gas exchanger since the volume to be handled hourly is considerably less. In schematic B 1 the beamhouse effluent is treated with ferrous sulphate and the combined wastes are aerated with a Kessener brush before sedimentation.

In schematic C 1 the flue gas exchanger is used only for the treatment of the beamhouse effluent before it is mixed with the other wastes from the tanning and colouring processes.

Schematic C 2 represents a modification, as it is suggested for a vegetable tannery. The beamhouse effluent is treated separately with flue gas before the combined wastes are introduced into an oxidation ditch equipped with Kessener brushes for aeration and biodegradation. It will depend on the individual situation and effluent condition whether the biochemical aeration treatment precedes or follows sedimentation. The possibility exists also to have a series of oxidation ditches before and after sedimentation.

The one problem which so often is not sufficiently taken into consideration when tannery waste is to be treated is the handling of the exceptionally large amounts of sludge. Tannery sludge, due to the colloidal nature of the proteins is highly hydrophilic and consequently very voluminous. Furthermore, it has a high retention for water and dries slowly on sludge drying beds. For fairly rapid drying, settled sludge should not be deposited in layers deeper than 18". By treating the beamhouse effluent with flue gas, the crystalline calcium carbonate is more compact and acts as a nucleus for the protein floc. Thus the sludge is more dense, settles more rapidly, requires less space in the drying beds, and dries faster. The drying bed, up to now, has still proven to be the most economical, least cumbersome disposal of tannery sludge. When its moisture content is reduced to about 60%, it is dry enough to be handled by a shovel to be disposed of on piles or directly transferred to fields for agricultural purposes. High on calcium and on slowly decaying nitrogen, it is a useful soil conditioner.

Filtration of tannery sludge has been tried with different types of equipment but up to now no successful and economical solution has been presented. In closing, you might be interested in viewing slides of the practical implementation of the described treatment.

Figure 4 shows an equalization tank. The rotating basket and the bottom rake prevent settling of solids in the equalizer.

Figure 5 shows the same tank with the overflow from the pumphouse. With the pump removing hourly only a carefully rated volume, the excess returns into the equalization tank. The day starts with an empty equalizer. There, the volume is built up to the maximum during the peak hours of plant operation to go down again to emptiness during the night.

Figure 6 shows the flue gas exchanger. In this older installation, a cooling tower was inserted into the flue gas line coming from the bridging. In the more recent constructions, the cooling tower has been omitted and the exchanger tank has been extended. The splash of effluent provided by the agitator inside the flue gas exchanger cools the flue gas rapidly.

Figure 7 shows the other end of the flue gas exchanger. The exhaust fan to move the flue gas is installed on the top of the tank. The flue gas is sucked through the tank to avoid contact of the fan with the hot flue gases. The motor and drive belong to the internal agitator.

Figure 8 shows the bridge carrying a Kessener brush straddling an oxidation ditch. The ditch can be made in concrete construction but it has been found that a ditch made by bulldozing is just as effective and much more economical. Only the structure supporting the bridge is made in concrete.

Figure 9 shows the concrete foundation as well as the arrangement of two brushes in the same ditch.

I hope that I was able to give you some information concerning the more recent approach to effective and economical tannery waste treatment.

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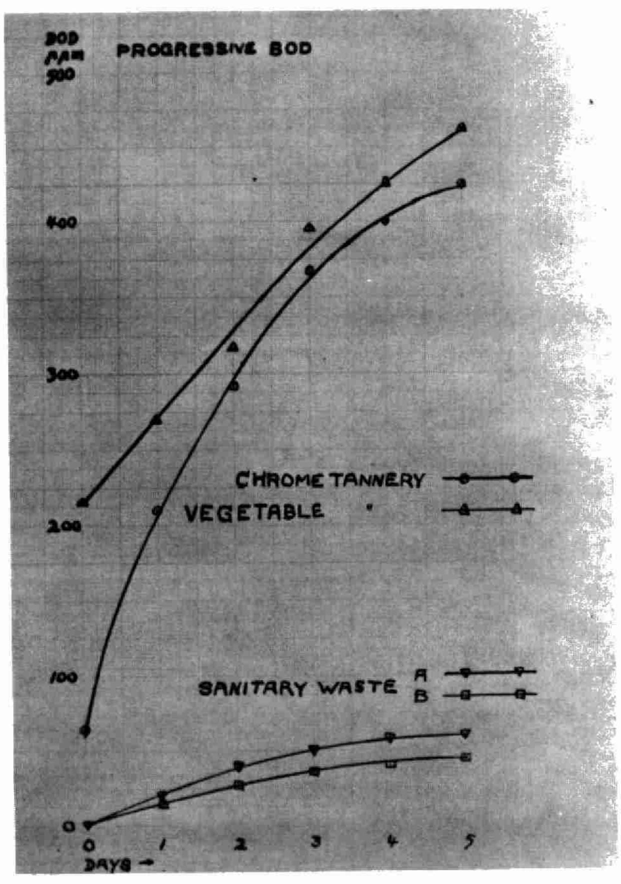


Figure 1

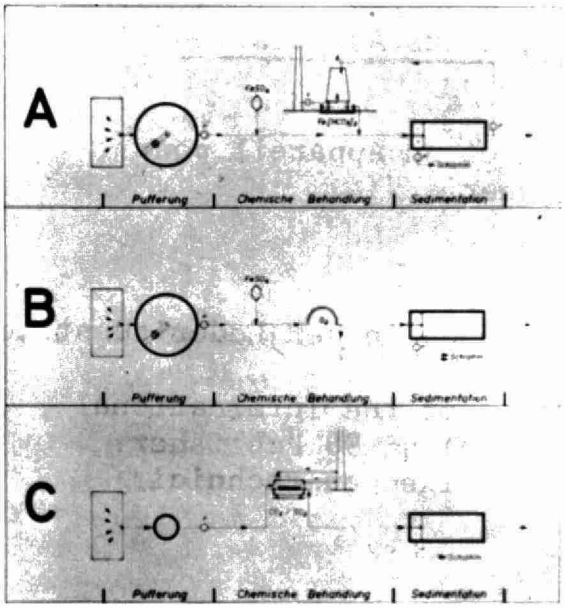
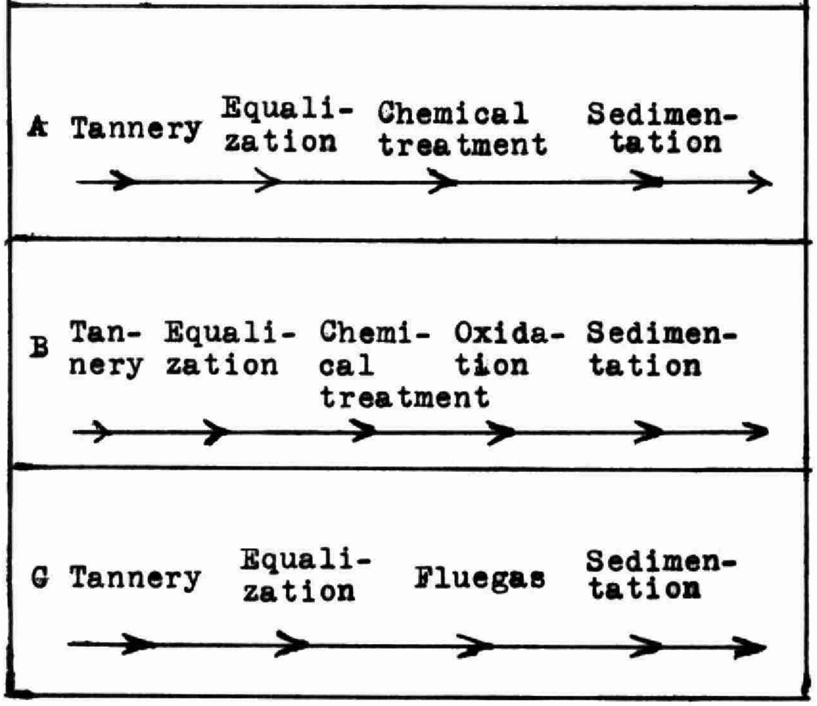


Figure 2



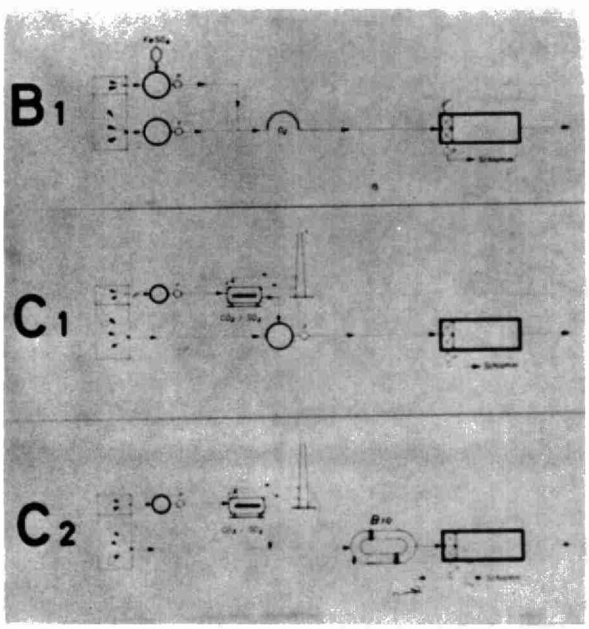
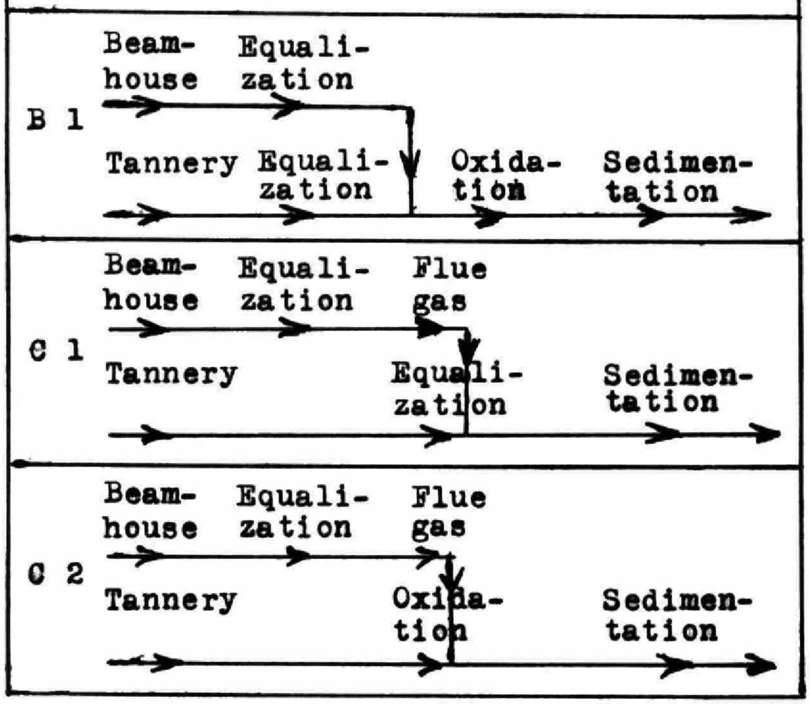


Figure 3



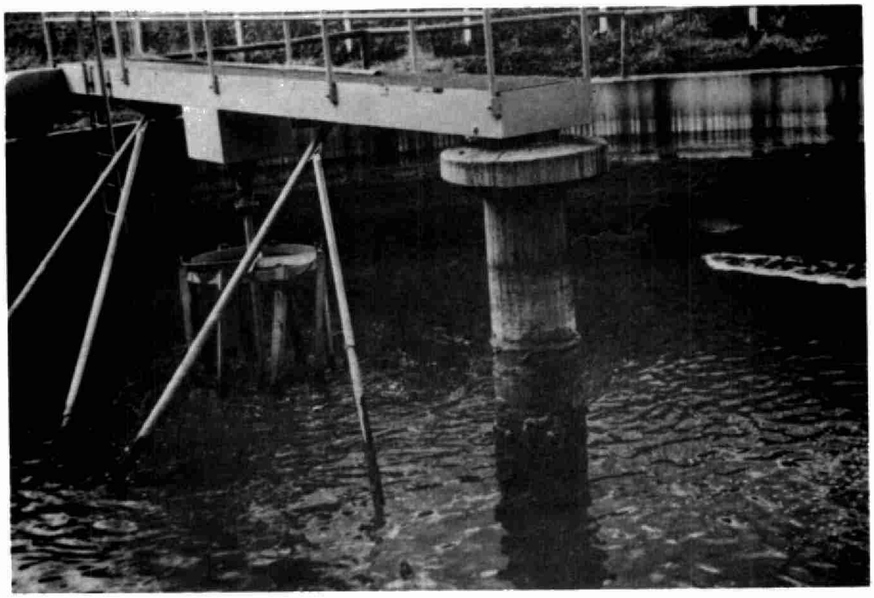


Figure 4

Figure 5

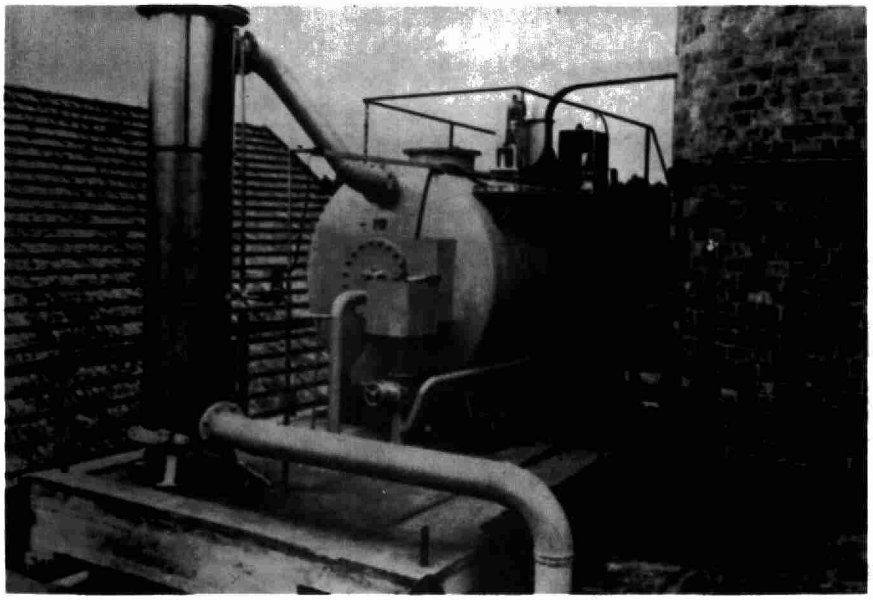
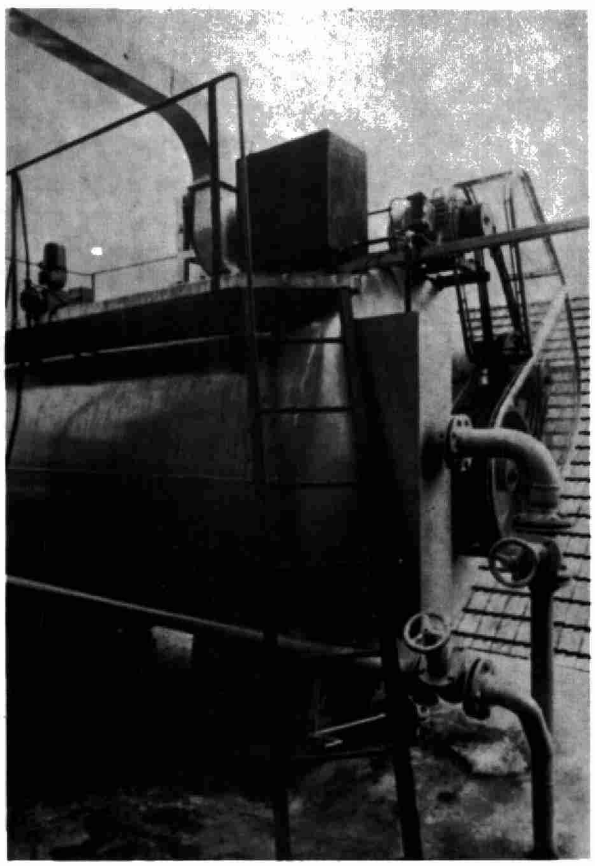


Figure 6



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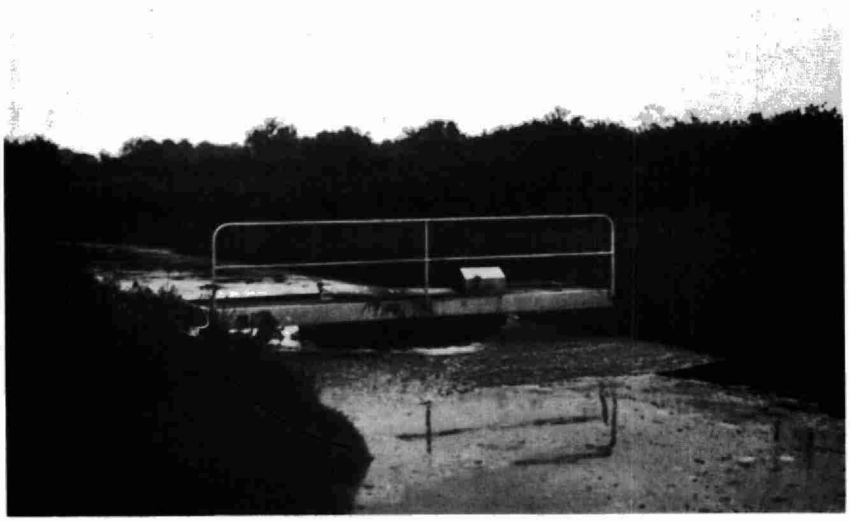

Figure 8

Figure 9

OPENING REMARKS

BY

Mr. D. S. Caverly

REGISTRATION

"TANNERY EFFLUENT DISPOSAL - FIFTEEN YEARS OF SPRAY IRRIGATION"

BY

R. R. PARKER

VICE PRESIDENT
BEARDMORE & COMPANY, LTD.

In choosing a theme for this paper, it was decided the cause of spray irrigation as a means of disposal of industrial waste could best be served by a review of the results of the experience of the author in operating a spray irrigation system over a period of fifteen years, and the relationship between the operational changes and the technical literature in the subject. In some instances, reports in the technical press corroborate this experience and, in other instances, however, the order was reversed.

Despite occasional differences of opinion which are to be expected, the conclusions of various workers over the years have indicated a rather close agreement in the details of operation and the usefulness of the method. During that period, the methods of operation along with the thinking behind them have undergone many changes. Phases of the operation once considered essential and unchangeable have diminished in importance to the point of oblivion. This has not simplified the task of the operator however, as a steady influx of new problems has developed over the years.

In carrying out the purpose of this paper, it has unfortunately been impossible to draw on practical

experience for every comparison. The author has been connected very closely with the problem of the disposal of effluent from a large tannery. While the nature of the effluent is not simple, it must be recognized that no one operation can offer all the problems that one might encounter, nor will it call for more than a limited number of answers.

The literature on spray irrigation fifteen years ago was not very detailed and the method was not widely used. According to Dennis (1) the first spray irrigation system for industrial waste was put into operation in 1947 for a cannery in Pennsylvania. Two years later, in 1949, a system for a milk processing plant was installed.

History of Acton Operations

For a general history of effluent disposal as performed in Acton, reference is made to a paper presented by this author at the Sixth Ontario Industrial Waste Conference in 1959 (2).

The earliest attempt at spray irrigation, if it is fair to use the term here, relied on a high degree of evaporation as an important factor. For justification of what now is a somewhat naive belief, two points should be remembered:

1. The only problem at that time was the disposal of gallonage, and any approach that might help in this direction was considered worthy of investigation.

2. As spray treatment was considered as only a supplement to the regular system, it was thought that a warm weather operation would suffice to dispose of the additional gallonage.

Preliminary tests indicated that a possible evaporation of 20% to 25% of the amount sprayed might be achieved. Under ideal conditions this might be achieved, but ideal conditions were far from common and the net performance was disappointing. The collection and handling of run-off below the large spray line became a serious and expensive problem and surface erosion was a major factor which had not been foreseen. It is natural to

question whether this is a factor to-day. The answer lies in the fact that in this earlier system, the application rate was in the order of 2 inches per hour, much higher than is considered good practice to-day.

The floating sprayline is hardly within the area of spray irrigation and again it was another attempt to utilize evaporation. It is a matter of regret now that this installation was not maintained for the study of B.O.D. reduction.

Attention was drawn to the very thorough work of Thornthwaite (3) (4) and based on these reports an attempt was made to adopt a somewhat similar procedure for the tannery, using a conveniently located wooded area.

Segregation of the tannery effluents had been effected at this time and the only satisfactory wooded area was near the lagoons holding waste vegetable tan liquors - an effluent with a B.O.D. of approximately 3,000 p.p.m. and pH 4.5. Geographically it was not convenient to apply the other effluent material - B.O.D. 800, pH 10.5 - to a wooded area and tests with this material in this cover have not been practicable.

The first installation for orthodox spray irrigation, if one might use that term, was a large nozzle with orifices of 3/4" and 1/4" and a rating of 200 IGPM. An application rate of approximately 3 inches per day was achieved. Unfortunately, the effluent was somewhat toxic to vegetation, a factor that had not been anticipated. After a year's operation, a gradual deterioration of the vegetative cover was foreseen.

Further tests with these large spray nozzles have been made, but on the grass cover currently used, erosion can be a major problem. Any appreciable drop in line pressure can affect the degree of atomization and the impact of an unbroken stream on wet grass is disastrous.

Certainly there is a great deal of advantage in the use of large nozzles. The smaller number of outlets simplifies the installation, and materially decreases the amount of labour required. Apart from the number of units, the plugging of the smaller orifices can be a problem. Where bush cover is available and there is no conflict because of the nature of the effluent, and of course with

sufficient volume to justify the larger units, the author would give primary consideration to the larger nozzles.

When the original low-line installations were made, the spray head was connected to the line through an offset tee, the tee being equipped with an 8" spike. This spike was forced into the ground to maintain the spray head in a vertical position which is most important for the prevention of grass damage. The tee arrangement was simple, inexpensive, and effective, but the use of bronze clamped saddles is considered to be a definite improvement. The listeners should be reminded here that this installation is made with polyethylene pipe, which, on the basis of many years' experience, still is to be preferred to other pipe materials. Using the saddle connection, there is no need to cut pipe in order to install spray heads, thus eliminating a number of pipe fittings. There is less chance of damaging fittings when a pipe line is moved and the in-line mounting renders grass-cutting easier. The preservation of the vertical position is simple - a spike is brazed to the lower section of the saddle.

One of the problems involved in spray irrigation in open fields - as contrasted with bush operation - is the care of the cover crop. There is ample corroboration in the literature for this statement. Blosser (5) treats this point in some detail as does Canham (6). Mr. Canham's reference deals with a particular phase of irrigation but the article treats in detail the necessity for adequate cover. Mention is made in the Canham article of the almost complete disappearance of alfalfa after a season's operation. This observation is in agreement with the Acton experience where heavy alfalfa and clover growths were killed in short order. Originally, and again reference is made to the author's former report (1), it was recommended that the grass should not be allowed to grow higher than 12 inches. Due to abnormal growth rates, occasional labour problems, weather interference and the like, this optimum frequently was exceeded. A heavy crop presents problems, wet grass is difficult to cut and the higher growths require a longer period of drying prior to cutting. Normally the sprays were shut off for a two-day period before cutting but, with weather variation, sometimes three to four days were required. After cutting and removal of the cuttings - and with cuttings of this length, removal is absolutely necessary - a period of two to three days for the re-development of green colour in the stubble is required before

spraying can be resumed. Without active growth, the likelihood of soil erosion is increased, and with heavy spraying, there is danger of crop damage. Thus, with each cutting, there is a period of possibly five to probably eight days when a field should not be sprayed. Under normal conditions three to four cuttings per season were necessary and consequently a loss of three weeks to a month of optimal use was incurred each season.

Conventional hay harvesting was used and, in addition to the waiting period, the system suffered from the soil compaction caused by the passage of tractor, mower, rake, loader and truck. A forage cutter was used and a unit composed of tractor, cutter and truck was used. This was an improvement but there was still the overlong waiting period. Eventually, a Mott Hammerknife mower was purchased and the cutting schedule altered to suit the new equipment. Using this cutter, the grass is cut when about 5 inches high and is cut to a 2 inch height. With this short growth the grass is left on the turf and provided the cutting schedule is maintained, there is no matting of the new growth. Canham (6) mentioned that all cuttings were allowed to remain on the field but in the author's experience, this, with long grass, was fatal to good growth. A field is cut and back in service within 24 hours and there is virtually no loss of service other than the actual cutting time. There is some saving of labour as well. Another advantage is the decreased soil compaction.

One might ask at this point why the operator failed to face facts and to become a hay grower. There are two answers to that question:

1. This was a tannery rather than an agricultural operation.

2. The storage and disposal of the resultant crop produced more trouble than profit. Experiments with sheep and cattle confirmed the usefulness of the crop but the acquisition and care of one thousand sheep or forty head of cattle was a task that had little appeal.

Some of the audience might wonder whether this is an engineering report or a lecture on field husbandry but in justification of this treatment, it is essential to realize that care of the cover crop is an essential part of a satisfactory spray irrigation operation.

It is interesting to note, in passing, that livestock can be fed a ration restricted to grass grown under a heavy spray of water saturated with calcium hydroxide and calcium carbonate, with pH 10.5, with adequate maintenance of weight and no effect on the flavour of the resultant meat. This might well be of use in solving the disposal problem for some industries where the applicability of other than water of normal pH might be a factor.

One more point in favour of the present grass cutting should be mentioned - again a labour saving feature. Using the new cutters and the in-line spray heads, it is possible to cut close to the pipe and the pipe need not be moved for every cutting. After three or four clippings a lateral movement of the pipe to a distance of one foot - an operation easily carried out by one or two men - is all that is required to maintain a uniform grass height over the field.

Another problem was that of odour. Storage of effluent over a period of months in deep lagoons permitted the development of an anaerobic action and the resultant effluent had a definite, although not overpowering odour. Unfortunately for our public image, a subdivision of considerable extent was developed down-wind from the spray area, inhabited in the main by other than tannery employees. Round-the-clock spraying in mid-summer humidity resulted in a series of complaints, and in the interests of public relations, some method of odour abatement was necessary. A large number of masking agents, essential oil combinations, and mixtures of the two were tested in the laboratory and the more effective were chosen for prolonged field tests. In practice, some were reasonably effective. Two methods of application were tried and both adopted. In one case the de-odorant mixture is fed through a drip-valve into the sump under the spray pumps. This is a general treatment and was adopted as standard practice during the mid-summer period. It has considerable effect but the cost is high. The required amount of material varied from 1 to 5 p.p.m. with the optimum usually about the median value of 2.5. Spraying 1,000,000 to 1,500,000 imperial gallons per day necessitated the use of 2 to 4 gallons of the material at a cost of approximately $7.00 per gallon. The amount may seem small but $25.00 per day over an extended period for odour control only, was deemed somewhat excessive. The second method is wholly temporary. In the event of serious odour development, use is made of

small motor driven fogmakers mounted down-wind from the spray area. The concentration used here is of course, much higher but the periods of use are so short that it is a more economical method of emergency control. The odour problem finally was solved for all practical purposes by a change of spray schedules. Beginning in the spring, as soon as the grass turns green, the application rate is increased at least three-fold. Sprays are operated on a 24-hour schedule and the greater part of the effluent accumulated in the lagoons is applied to the land before the advent of hot weather. The stronger winds of spring add the effect of dilution and the operation is almost odour-free. As a result of this accelerated operation, evening and night-time spraying in mid-summer were not required and the incidence of complaints decreased almost to the zero point. In addition, the use of odour control compounds was cut to a minimum, as development of odour is mainly an evening and night occurrence.

In attempts to improve this operation, an interesting experiment was tried with little or no success, and to date, no explanation for this failure has been found. As a result of tests in a soil column equipped with effluent drains at various heights, it was demonstrated that passage of effluent through a soil bed 5 feet thick would produce an effluent water-white and with a B.O.D. equal to or less than the OWRC objective of 15 p.p.m.

An area of approximately 0.5 acres was fitted with underdrains of perforated plastic pipe installed in trenches 6 feet deep, the pipe being laid in a bed of coarse gravel. The ground was carefully chosen in order that the discharge pipe from the under-drain manifold could be brought out to a lateral slope and the system drained by gravity. A standard spray system was installed, after a grass cover had grown, and this area was sprayed at the normal application rate and also at a rate several times that customarily used. The effluent was clear and colourless, or cloudy, dark and foul-smelling and the B.O.D. figures varied from a satisfactory 10 p.p.m. to a disappointing 300 p.p.m. Results were erratic and there has been no explanation for this aberration. Channelling due to poor back-fill of the trenches was considered but even after three years of trial, no consistent behaviour was encountered. It had been hoped, of course, that a much smaller spray area might suffice, particularly as the column tests had been so promising, but to date nothing of

use has been developed. Unfortunately, a lack of opportunity, followed by new construction in that area, terminated the experiment. Reports by other workers have varied widely and a study of the literature available failed to develop any confirmed opinion on this operation. Schraufnagel (7), while discussing ridge-and-furrow methods primarily, mentioned the same lack of agreement.

As pointed out, application rates vary widely. During the spring, effluent is sprayed at the rate of up to 2 inches per day. This rate does not cause undue puddling and at no time is surface run-off from either gentle or severe slopes tolerated. This rate is considered excessive for continued application and thanks to the amount of sprayable land available, summer loading is at the 0.3 inches per day level. This reduced loading diminishes the cost of turf maintenance and provides a large degree of flexibility in the spray schedule. Normally, the fields in operation are sprayed for two two-hour periods each day but in the event of pump failure or other trouble, the spray time may be doubled without serious effect.

Winter spraying, as a consistent operation, has not been achieved. It has been possible to spray during the warmer part of the day in December or even early January, provided that there has been no extended period of cold weather (20^{o}F. or less) but the application period must be curtailed so that there is no build-up of ice on the turf. Once that occurs, the season is over. Ice cover, in the experience in Acton, must be avoided, as the grass is injured, the onset of spraying in the spring is delayed, and there is always some danger of run-off.

Normally spraying extends from late April or early May to late November or mid-December and lagoon capacity for the storage for a minimum of five months' effluent must be provided. If there be a critical point in the use of spray irrigation, it lies in this necessity for adequate lagoon capacity. Small amounts of heated material could be sprayed in the winter and the literature mentions several examples of this practice, but in the author's experience, this would be a very limited application. It is interesting to note that Fisk (9) describes a system operating in Western Michigan throughout the year but an area of 35 - 40 acres in a system of 140 acres is given a continuous application of warm water in the winter period.

Other workers have referred to winter spraying as a possible operation but specific performance figures have not been quoted. In general, definite statements have referred to the inability to spray rather than the reverse.

Other authors writing on this subject have stressed two points, insofar as the composition of the effluent is concerned. Lawton et al (10) and Blosser (5), to cite two, indicate that the B.O.D. loading should not exceed 200 lb./ac./day. That figure has not been exceeded, on a seasonal basis, but application rates of two to three times that amount have been maintained over a period of one month. Because of the happy circumstance of the situation in a smaller community and company ownership of an ample quantity of suitable land, it has been possible to operate at an overall application rate of approximately 50 lb./ac./ day.

The second and potentially more serious point has been the possible effect of the high sodium content of the effluent. Again, several authors have warned of possible soil deterioration, as Blosser (5) and Webber (8). Blosser recommended an S.A.R. below 8. Due to the appreciable amount of sodium chloride in hides, tannery wastes, in consequence, have a high chloride content--the recent Acton figure is approximately 3,300 p.p.m. as NaCl. The resultant sodium adsorption ratio is 30, somewhat higher than any acceptable figure, insofar as a literature search could determine. However, when one recalls that the effluent is saturated with respect to calcium carbonate and calcium hydroxide, and in addition the suspended and nonsettleable solids, amounting to 200 p.p.m., are principally calcium compounds, there is some explanation for this seemingly contradictory situation. The spray operation distributes approximately 1 ton of calcium carbonate per acre per year, which is considered to be a fairly satisfactory remedial treatment. Certainly there has been no appreciable decrease of the ability of the area to handle the gallonage applied.

Costs:

Capital expenditure comments can be misleading in that the cost of acquiring land is subject to wide variation. However, spray irrigation is hardly an urban operation and prime grade arable land is not an essential. For the moment disregard the land cost. Considering an area of 10 acres

and using the same lay-out followed in Acton, it is estimated that the installed cost would be approximately \$20,000. This figure includes pumphouse, pump, electrical connections, piping and heads. Preparation of the cover crop would cost a maximum of \$500.00. The installation should be capable of accepting 200,000 gal. per day.

Maintenance expense, including power and labour, should be in the order of \$20.00 per day or 10¢ per 1,000 gal. Amortization of capital over a 5-year period would double this figure for an anticipated total cost of 20¢ per 1,000 gal.

At this point many a plant owner might point out that the figure of 20¢ per 1,000 gal. is high, even higher than some municipal sewage treatment charges, and certainly higher than the cost of present somewhat haphazard methods of treatment. Of course, it is higher, but one must compare the results of this and other forms of treatment. Most of the audience would agree that 95% removal of B.O.D. by a bio-oxidation process is a remarkably good performance. In the system outlined, remember the influent figure of 800 p.p.m. B.O.D. and that this performance would produce an effluent of 40 p.p.m. B.O.D., almost three times the acceptable figure, and in the Acton area, a completely unacceptable load for the low-volume creek that is the only drainage course. It is certain that everyone in this audience has read rather enthusiastic accounts of treatment processes where B.O.D. removal of 60% to 75% was achieved. How can this be reconciled with the local conditions described above? Spray irrigation is not the only method of disposal, and in many cases it may not be the preferred one, but it certainly should be considered in any test of possibilities, and in some cases, it may provide the difference between success and failure or its industrial consequence of operation or shut-down.

The costs given above should be regarded as maximum figures. The type of effluent - its toxicity to vegetative cover, etc. - may permit modifications that allow considerable savings. For example, a 10-acre plot laid out with large spray heads would cost approximately half the system previously outlined and the operating charges would be slightly lower. If bush spraying is possible, then the labour charge again will be decreased because there will be no need for cutting the cover crop and a resultant figure of approximately 10¢ per 1,000 gal.

can be expected, a rather low figure when one remembers that a five-year write-off of plant is included.

There are problems connected with this method, as with other disposal systems. One of the more obvious is that of ground water contamination, particularly with inorganic contaminants. In the Acton plant there is no problem from B.O.D., chrome compounds, sulphides, or suspended solids. The one constituent for which no satisfactory answer has yet been found is sodium chloride. The removal of salt from solution can be achieved, but what does one do with salt, and dirty salt at that? The problem of salt removal is not one that can be effected by spray irrigation, but it is mentioned as a possible complication that should not be overlooked or ignored. Any inorganic contaminant could produce a similar problem and as long as aquifers with useable water are close to a disposal area, there is at least a possibility of trouble. Where chemical treatment can be employed, it may well be followed by land disposal, but again it is a question of volume and concentration as to whether a local problem is solved or compounded.

Conclusion:

An attempt has been made to trace the reasons for operational changes in a spray irrigation system covering approximately 100 acres, where tannery wastes to the amount of approximately 100,000,000 imp. gal. per annum are treated. The system, which has functioned without serious problems for fifteen years, is offered as a practical plan for operations where similar conditions are encountered. Capital and maintenance costs are reasonable and under certain circumstances, can be considerably lower than the present model.

Spray irrigation is only one of several disposal methods which, when properly applied, may well be the answer to many effluent problems. It can be said without fear of successful contradiction, that continued operation of the Beardmore tannery would not have been economically possible without the installation of this system.

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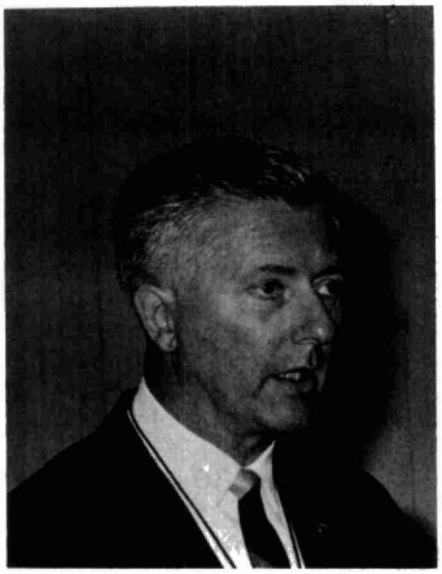

"TREATMENT OF MEAT PACKING WASTES - PRACTICES AND TRENDS"

BY

A. J. STEFFEN
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Slaughtering and meat processing operations produce a characteristically high organic, highly nitrogenous, biologically degradable wastewater, with relatively high concentrations of suspended and dissolved solids and grease. The waste does not vary as widely in characteristics and concentration as might be expected from the wide range of processing operations and waste conservation practices found in the industry (Table #1). However, there are no average plants and no average conditions; therefore, the figures in Table #1 should not be used without a careful study of plant characteristics and processing program and then only for new plants where analytical data are not available.

The size of the plant affects the characteristics of the wastes as well as the volume. Very small abattoirs (slaughterhouses) may not save blood, and some do not provide grease recovery. Some small plants may wet-render but may not have facilities for evaporating the tank water, the liquid by-product of the process. The BOD of tank water and blood will run as high as 30,000 mg/l or more. Most rendering plants are now dry-rendering, which produces no tank water, but "skimmings" from grease recovery tanks are still generally wet-rendered because of the large amount of water in the skimmings.

Table #1

Approximate range of flows and analyses for slaughterhouses, packinghouses, and processing plants[a]

Operation	Waste flow Imp. gals per 1000 pounds live weight slaughtered	Typical analysis, mg/liter		
		Biochemical oxygen demand	Suspended Solids	Grease
Slaughterhouse	420-1700	2200-650	3000-930	1000-200
Packinghouse	600-3000	3000-400	2000-230	1000-200
Processing Plant	850-3500	800-200	800-200	300-100

Approximate waste loadings[a]

	Pounds per 100 pounds live weight slaughtered		
Operation	Biochemical oxygen demand	Suspended Solids	Grease
Slaughterhouse	9.2-10.8	12.5-15.4	4.2-3.3
Packinghouse	18.7-11.7	12.5- 6.7	6.3-5.8
Processing plant	6.7[b]	6.7[b]	2.5-3.3[b]

[a]From "An Industrial Waste Guide to the Meat Industry," Public Health Service Publication No. 386, Revised 1965, p.6.

[b]per 1000 pounds finished product.

By-product Recovery

Blood, casing slimes from stripping operations, and tankwater can be concentrated or dried and utilized in feeds and fertilizers. If the protein values of the feed and fertilizer ingredients produced at the plant are higher than the requirements of the particulr fertilizer being produced, quantities of lower grade materials are sometimes blended with these materials.

The recovery of floatable fat from the wastewater is standard practice. To limit the size of recovery basins, grease bearing wastes are segregated. The basins are generally rectangular, 4 to 6 ft. deep and large enough to provide three quarters to one hour's detention at maximum flow. The basin may be hand skimmed in small operations but is generally mechanically skimmed in larger plants. In most cases, mechanism for sludge removal is also provided but some basins are designed to carry settleable solids out with the effluent. The addition of polyelectrolytes has been found to improve grease yields. Air flotation is popular, either by direct aeration or by pressurized air introduced into the effluent or a portion of recycled effluent. Alum improves separation but has the disadvantage of producing alum soaps when the resulting scum is wet rendered.

In recent years, the disposal of paunch manure has become a vexing problem. Paunch manure is washed out of the paunch (first stomach of cattle and other ruminants) on the killing floor. The resulting wastewater is generally kept separate from the fat bearing wastes because it contains very little fat and a large quantity of partially digested hay, grass and corn. The paunch content of cattle is estimated at 40 to 60 lbs. per head, has a volume of about 1 cu. ft. before dilution and contains about one fifth to one third pound of BOD[2]. The solids are generally concentrated by screening, either with mechanical screens or by leaching through stationary screens. Some use is also made of expellers and presses. In most cases, paunch solids are disposed of direct to farmers as fertilizer or as land fill. In some cases, such as at South St. Paul, Minnesota and at St. Joseph, Missouri, paunch manure is discharged with the plant wastes to the city sewer for segregation at the municipal treatment plant. At South St. Paul a private firm has, until recently, been drying primary solids but the [illegible]

production has far outstripped demand. The firm is no longer in business and the solids are piling up. In Omaha, Nebraska, the packingtown sewer has not been tied in to the new municipal treatment plant because the paunch manure discharged by the city's 19 abattoirs and packing plants cannot be handled. Multimillion dollar disposal methods are being considered by the city and industry engineers.

Trickling Filters

The work of Levine and others at Mason City, Iowa[3] in 1937 led to construction of plants at Mason City and South St. Paul, Minnesota, employing washable trickling filters in series. These were large plants, particularly at South St. Paul where wastes from several plants are treated. This system has also been applied in a new plant at Rochelle, Illinois, which achieves 95% BOD removal with three-stage filters following grit removal, mechanical flocculation and sedimentation. A conventional two-stage high rate trickling filter plant in Madison, Wisconsin, accomplishes 85% removal.

Disposal by Irrigation

Since meat industry wastes contain relatively high concentrations of nitrogen and phosphorus, disposal by irrigation should be attractive. However, although many systems of ridge and furrow, spray and broad irrigation are successfully disposing of canning, dairy and paper mill wastewaters, there are few in the meat industry.

One spray system in Rushville, Illinois, disposes of the effluent from a lagoon receiving meat packing wastes. Another in Madison, Wisconsin, using several types of flood and spray irrigation, disposes of trickling filter plant effluent (200 mg/l BOD) from a large packing plant. Eight years of study of the system in Madison showed improved crop yields on all soils tested.[7] Miami silt loam removed 50% of the nitrogen, 40% of the phosphorus, and 60% of the potassium. Improved crop growth on these soils was due primarily to the nitrogen. On peat soils the crops removed nearly 80% of the nitrogen, 50% of the phosphorus, and more than 55% of the potassium. In these soils the researchers believed that phosphorus and potassium caused the increase in yield. Application rates were as high as 39,000 gal/day/acre with no leaching

of nutrients into a drainage creek 30 ft. away. The irrigation area was cropped with Reed's canary grass and was irrigated by flooding and by movable spray systems. The studies also demonstrated that conservation practices and separate treatment of the wastes from meat curing can keep salt concentrations in packing plant wastewaters below the optimum allowable limits to prevent soil damage.

In New Zealand, 420,000 Imp. gal/day of raw meat packing wastes are discharged by ridge and furrow irrigation onto 80 acres of sheep grazing land[8]. The area carries an average of 25 sheep per acre, increasing to 100 per acre in summer. Application is about 50 inches per year.

The only known irrigation system in the United States treating raw wastes from a packing plant is at Elburn, Illinois, where 200,000 Imp. gal/day are sprayed, after grease recovery, onto a 32 acre field planted in alfalfa and brome grass. The spray system consists of 13 conventional irrigation-type spray nozzles, each discharging 14 Imp. g.p.m., on risers about 12 inches above aluminum distribution piping. The spray system covers one-sixth of the area, and is moved daily, irrigating at 2 in./day, with six days' rest. Crop yields have been so high that the owners have now purchased additional land to make full use of the fertilizing potential of the wastes. During the winter months the spray system was set up on a limited area of four acres in order to build an ice pack. The nozzles were extended 4 ft. off the ground to facilitate servicing during the winter. The ice pack melted slowly during the first thaw and the runoff joined that from the farm fields in the area, flowing to a nearby stream which, at the flood stage normally associated with that period of the year, provided more than adequate dilution.

Irrigation warrants further study particularly in the areas of crop selection and the possibility of disease transmission by way of feed crops.

Stabilization Basins or Lagoons

Types The popularity of stabilization basins, for partial as well as complete treatment of meat industry wastes, has increased in recent years, stimulated by developments in the pond treatment of municipal wastewaters and by research in anaerobic fermentation. The

following types, including both partial and complete treatment, are currently in active use:

1. Anaerobic (deep) ponds to reduce the strength of wastes prior to discharging to a municipal plant.

2. Complete treatment in aerobic ponds, generally in series and preceded by good grease and solids recovery.

3. Complete treatment in anaerobic-aerobic systems, in series, usually consisting of a single deep anaerobic pond, followed by one or more shallow aerobic ponds in series.

4. Further treatment ("tertiary") following anaerobic contact or conventional aerobic secondary treatment.

<u>Anaerobic (deep) Ponds for Pretreatment</u> Dietz[9] reports that a new full scale anaerobic pond treating packing plant wastes at Union City, Tennessee, which first overflowed in mid-September, 1965, showed 80% BOD removal two weeks later at an average loading of 7.9 lbs. BOD/day/1000 cu. ft. The pond was seeded with anaerobic sludge from a nearby pilot pond. In recent months loadings have exceeded the design loading of 15 lbs. per 1000 cu. ft. but BOD removals exceed 80%. The pond effluent is discharged to a municipal activated sludge plant.

Porges[10] reports data on 29 anaerobic ponds treating meat and poultry plant wastes: a median area of one acre, median depth of 7.3 ft. and median detention time of 16 days. Of the 16 reporting BOD data, loadings ranged from 175 to 6,060 lbs/day/acre (median 1,260), with removals of 65 to 95% (median 80%). It is unfortunate that Porges reported anaerobic pond loadings on an area basis rather than volume since the loading of this type of pond is a volume characteristic and has no relationship to surface area.

<u>Aerobic Pond Systems (complete treatment)</u> Reported loadings in conventional aerobic stabilization pond systems range from 50 lb/day/acre[11] treating raw meat packing wastes in South Dakota, to 214 lb/day/acre treating

relatively dilute poultry processing wastes in Delaware (BOD 175 mg/l) following primary sedimentation and flow equalization[12]. The difference in loading is due largely to the benefit of primary clarification in the Delaware plant.

Extended aeration in ponds should be useful for meat industry waste treatment but no information is available on existing plants. However, poultry slaughtering wastes are being treated by this process in Kettleby, Ontario, in a 15 ft. deep completely mixed two-stage aerated lagoon[13]. Data supplied by OWRC show an average raw BOD of four composite samples collected in April and May, 1966, to be 445 mg/l, and an average effluent BOD of 55 mg/l for the period of November, 1965 to March, 1966. This system is equipped with 36 Aero-Hydraulic guns for mixing and aerating and 3 for an hydraulic barrier to divide the basin into two parts.

Porges[15] reports a median loading of 72 lbs/day/acre (14 to 250 lbs/day/acre) for 50 aerobic pond systems treating wastes from the meat and poultry industries. Depths ranged from 1.5 to 9.0 ft., with a median of 3.0 ft. and areas ranged from 0.04 acres to 75 acres, with a median of 1.3 acres, providing detention of 3 to 326 days, with a median of 70 days.

Anaerobic-aerobic Pond Systems, (complete treatment)

The first reported system for this type, at Moultrie, Ga.[16] has been operating since 1955, treating meat packing waste in an anaerobic pond 14 ft. deep, with a capacity of 3.5 million imperial gallons followed by an aerobic pond, at a BOD loading of 0.014 lbs/day/cu. ft. in the anaerobic and 50 lbs/day/acre in the aerobic stage (four year average). Indicative of the space saving of this type of pond treatment, the overall BOD surface loading was 325 lbs/day/acre. Sludge is recirculated in the anaerobic pond and effluent is recirculated in the aerobic stage. The BOD of the raw waste averaged 1,100 mg/l and the effluent averaged 67 mg/l. A second system installed by the same firm at Wilson, North Carolina, consists of an anaerobic lagoon 17 ft. deep with 3.5 days detention, followed by trickling filter treatment in the municipal plant. At each of these plants grease, paunch manure and gross solids are removed in pretreatment facilities. To reduce excessive solids concentration in

the anaerobic pond, some sludge was removed after two and a half years in service, and was dried in a nearby field without nuisance.

Two lagoon systems treating packing wastes in New Zealand, each with about 1½ days detention in the anaerobic pond and 5 to 7 days detention in the aerobic ponds, produce 90% BOD reductions during the annual 6 months' kill practiced there. The ponds are recirculated and, at last reports, degasification of the effluent, followed by sedimentation, was planned to provide further BOD removal.

There is evidence that the discharge of paunch manure to anaerobic basins may be beneficial, presumably by forming a scum that resists penetration of air and sunlight. A system in Idaho, consisting of 3 ponds in series with a total area of 2.8 acres and 8 ft. deep, is so overloaded with a packing plant waste that includes paunch manure and other solids, that it is entirely anaerobic. However, the raw BOD of 1430 mg/l is reduced to 490 mg/l at a loading of 520 lbs/day/acre. The reduction is only 66% but the high capacity of anaerobic ponds for BOD removal is evident.

Twelve small rural abattoirs in Louisiana are successfully treating the entire plant wastes[17] in three-stage pond systems, each consisting of an anaerobic pond, a transitional pond, and an aerobic pond. The paunch manure, grease and blood are discharged with the raw wastes without pretreatment of any kind. The paunch manure and grease provide a mat on the anaerobic pond; difficulties in the anaerobic stage of treatment were experienced until this mat developed. Based upon an estimated BOD of 2000 mg/l and a flow of 650 Imp. gal. per 1000 lbs. of live weight kill, the anaerobic ponds were designed at 30,000 pounds live weight kill/day/acre-foot, the transitional ponds at 150,000 pounds, and the aerobic ponds at 75,000 pounds. The anaerobic pond is 10 to 15 ft. deep. There is no recirculation or supplemental heating in the systems. An average of composite samples taken at three plants gave a raw BOD of 2,270 mg/l, anaerobic effluent 183 mg/l, transition pond effluent 85 mg/l, and aerobic pond

effluent 56 mg/1. with an overall BOD removal of 98.5%.

Porges[18] reports that 10 anaerobic-aerobic pond systems treating meat industry wastes averaged 94% BOD removal, at BOD loadings ranging from 19 to 1,885 lb/day/acre (median 267).

Design criteria for anaerobic-aerobic systems vary. State regulatory agencies in Illinois, Iowa, Nebraska, Tennessee, Pennsylvania and Minnesota accept design loadings of 15 lbs. BOD per 1000 cu. ft. of anaerobic pond, allowing 60% BOD removal[19], followed by some form of aerobic treatment. Aerobic ponds used in series following anaerobic ponds range from 100 to 150 lbs/day/acre BOD loading (with 60% removal in each stage).

In one case in Iowa, an approved design followed these criteria: anaerobic pond at 11.5 lbs per 1000 cu. ft., 60% BOD reduction (raw BOD at 1250 mg/1); a mechanically aerated lagoon at 50 lbs. per 1000 cu. ft., allowing 50% BOD removal; and two natural aerobic stabilization ponds, the first at 200 lbs. BOD per acre, and the second at 100 lbs. per acre, allowing 60% removal for each. This total four-stage plant was designed to produce an effluent of 45 mg/1 (winter conditions). The system has been in use for about eight months and no data are as yet available.

Behavior of an anaerobic-aerobic pond system treating abattoir wastes under cold winter conditions was reported by Rollag and Dornbush[26]. At an ambient air temperature of 25.4°F and raw waste temperature of 82°F, the coefficient of conductivity in the first of two anaerobic ponds was 8.0 BTU/hr/sq. ft. of surface/Δ°F (water-air) while the second was 23.4. The difference was attributed to an 8" scum layer on the first pond, while the liquid surface of the second pond was exposed directly to the air. BOD loading was 16.1 lbs.. per 1000 cu. ft., with 58.2% removal. Subsequent treatement of the anaerobic effluent in aerobic ponds at 34 lbs./day/acre resulted in 13 to 30 mg/1 BOD in the final effluent. Under ice

cover, the BOD in the aerobic ponds exceeded 200 mg/1.

Aerobic Ponds for Further Treatment (Tertiary Ponds)

No data is available on this type of pond when used in conjunction with conventional aerobic secondary treatment receiving meat industry wastes, but results may be expected to be similar to those experienced with domestic sewage except that the higher levels of nitrogen and phosphorus would tend to produce more algae. Data on this type of pond following an anaerobic contact type plant treating packing plant wastes are given in a later section.

Odour Problems

Some odours may be expected. Of thirteen aerobic pond systems treating meat industry wastes, five reported odours at nuisance levels; of ten anaerobic ponds reporting, nine reported nuisance odours[20].

Odours carry about a mile from a series of three anaerobic cells treating meat packing wastes in Edmonton, Canada, according to a report by D. R. Stanley at the 1965 Ontario Industrial Waste Conference.[27] However, with nine days theoretical detention, they remove over 70% of the BOD and about 75% of the suspended solids. Mr. Stanley concludes that anaerobic ponds are satisfactory for treating meat industry wastes if they are located sufficiently remote to avoid odour nuisances.

Topography, weather, intervening trees and the direction of prevailing winds are variables that complicate odour evaluations.

The Modified Anaerobic Contact Process

When digested anaerobically at temperatures of 90° to 93°F, packing plant wastes will produce a quantity of methane gas which, when burned, will raise the waste temperature about ten degrees. This is sufficient to sustain the digestion temperature since the temperature of raw meat packing wastes is normally

at 82° to 86°F. Most other industrial wastes that satisfy nutrient requirements for anaerobic metabolism are not warm enough to economically justify treatment by this process.

The first full-scale modified anaerobic contact process for the treatment of meat packing plant wastes was placed in operation in December, 1959, at Albert Lea, Minnesota[21 22 23 24]. The design was based upon pilot scale studies conducted at Austin, Minnesota[25], and upon studies on a first-stage plant designed to treat half the wastewater from the Albert Lea packing plant. Since 1959 other plants of this type have been built at Austin, Minnesota and at Momence, Illinois[26]. The completed plant at Albert Lea is shown in Figures 1 and 2. Figure 3 shows a schematic flow diagram of the process.

The plants at Albert Lea and at Momence are similar in design. Each is equipped with an equalizing tank to equalize the flow over a full 24-hour period. Preliminary treatment consists of gravity grease and solids removal (one half to one hour detention). Digestion takes place in totally mixed concrete digesters into which the raw wastes, preheated to 90° to 93°F, are discharged. The detention time in the digesters is 12 to 15 hours based upon the flow of raw wastes. The mixed liquor with suspended solids concentrations ranging from 7,000 to 12,000 mg/l, is digesting actively as it leaves the digesters, to be discharged through specially designed vacuum degasifiers to two gravity sludge separation tanks. The degasifiers remove residual gases to facilitate gravity separation.

The vacuum degasifiers are gas-tight steel vessels elevated to receive the digester effluent, which is drawn up under 20 inches of mercury vacuum by wet vacuum pumps. In the vessel, the liquid cascades down over slatted trays to enhance degasification. The gas as drawn off by the vacuum pumps is wet, contains high percentages (40 to 60%) of CO_2 and is thus highly corrosive. Corrosion protection consists of a baked phenolic lining and galvanized slats in the degasifier,

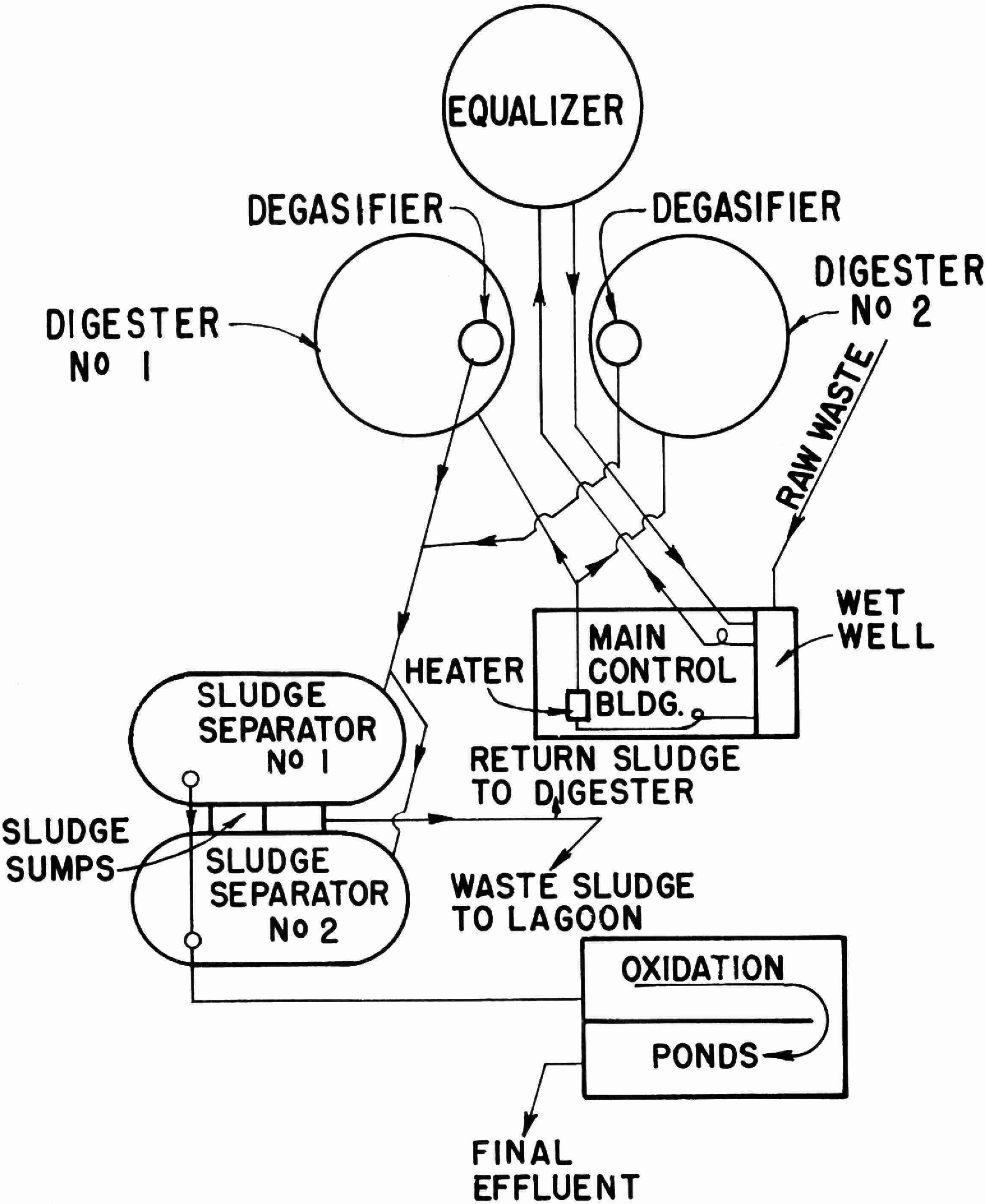

FIG. 1

ANAEROBIC CONTACT PROCESS, ALBERT LEA, MINN.

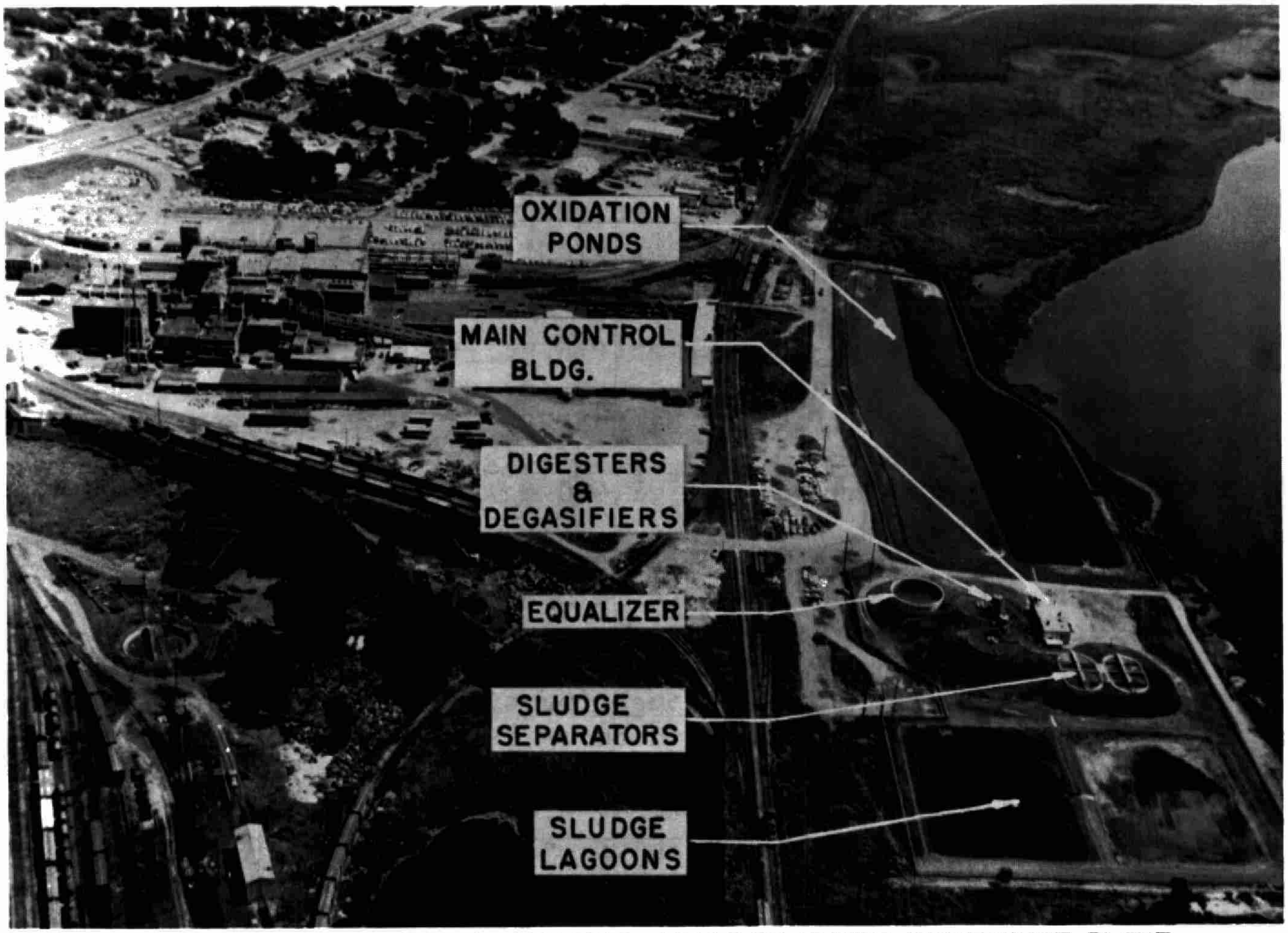

FIG. II - FULL SCALE ANAEROBIC CONTACT WASTE TREATMENT PLANT
WILSON & CO., INC. ALBERT LEA, MINNESOTA, U.S.A.

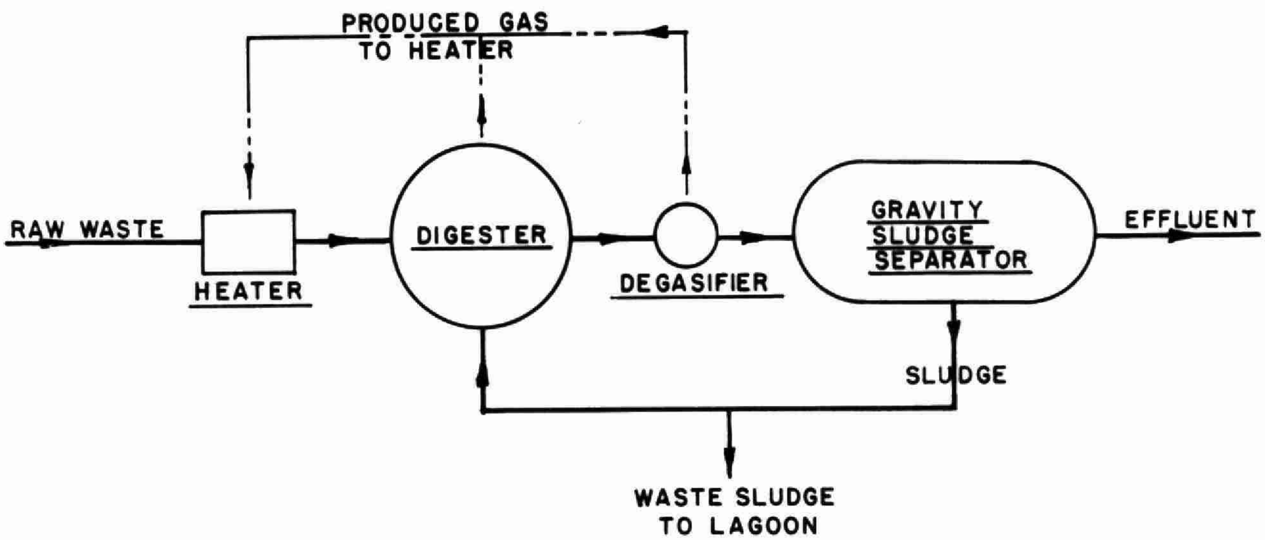

FIG. 3 - FLOW DIAGRAM - ANAEROBIC CONTACT PROCESS

stainless steel pumps and plastic piping. This "vacuum gas" is mixed with the gas generated in the digesters, which contains about 85 to 90% CH_4 and 10 to 15% CO_2, and is then burned in the boiler.

The plant at Austin utilizes air to purge the residual gases and operates at a lower BOD loading, removing 96% of the BOD at loadings of 0.1 to 0.06 lbs/day/cu.ft. of digester capacity, treating a raw waste of 1,400 mg/l BOD.

The sludge, in each case, is returned to the digesters as seed to maintain the anaerobic culture. The detention time in the separators is about one hour, based on total flow, including sludge circulating through the system at 3 to 4 volumes per volume of incoming raw waste. The surface settling rate is about 250 Imp. gal/day/sq. ft. based on raw flow only. In spite of the fact that the residual gases are removed in the degasifiers, the sludge is still flocculent and must be removed with suction-type rather than scraper-type mechanism.

The treated effluent overflows into weir troughs and is discharged for final polishing at Albert Lea to two oxidation ponds, and at Momence to an activated sludge plant. At Austin the effluent may be treated in the municipal trickling filter plant or discharged to the receiving stream.

The ponds at Albert Lea are 3.7 acres in area and 3 to 4 ft. deep, and reduce the BOD of the anaerobic effluent 50 to 70%, producing an oxygenated final effluent suitable for discharge into an adjoining lake. Because of reduced BOD removal during the winter months, additional ponds were recently constructed to dispose of the effluent by soil percolation.

The anaerobic contact process is similar in many respects to the activated sludge process. As in the activated sludge process, the first phase of treatment is largely stabilization by contact between the organisms and the nutrient in a favourable environment. After contact, the sludge, consisting

of organisms and agglomerated organic matter, is separated from the treated liquid and returned to the process to serve as seed for incoming wastes. The organisms digest the organic matter in the sludge mass during the recycling and treating process.

In the anaerobic process at Albert Lea the sludge age is about 5 days and the BOD loading is about 0.25 mg BOD per day per mg mixed liquor suspended solids.

Operating data for the Albert Lea plant, based upon daily analyses of samples composited automatically in proportion to the flow, are shown in Table 2. The relative capacity of the anaerobic process in removing BOD is shown graphically in Figures 4, 5, and 6. It will be noted in Figure 4 that the process regularly removed 1,000 to 1,450 mg/l of BOD, while the oxidation ponds removed a much smaller proportion of the load. However, the oxidation ponds act as shock absorbers, producing a final effluent of relatively uniform quality under a wide range of loading. The first pond, which is usually anaerobic, accounts for most of the BOD removal in the pond system. The average BOD loading to the ponds was 410 lbs/day/acre, averaging 129 mg/l BOD and 198 mg/l suspended solids.

Results at Momence show 86% BOD removal through the anaerobic unit and 77% through the activated sludge plant, yielding 97.0% overall BOD removal.

SUMMARY

Miscellaneous Treatment Processes

Conventional aerobic processes have found limited use in the treatment of meat packing wastewater. Washable trickling filters have been used successfully in 3 or 4 installations, Conventional activated sludge treatment has had varied success, and has generally required some pretreatment such as roughing filters to reduce BOD concentrations and iron out peaks. Extended aeration systems are in successful use in the treatment of poultry processing.

TABLE #2

Anaerobic Contact Process Treating Meat Packing Wastes

Albert Lea, Minnesota

Average Operating Data --- All Killing Days in 1960

	RAW WASTE	ANAEROBIC PROC. EFFLUENT	POND EFFLUENT	LOSS IN PONDS
FLOW IMP. GALS.	1,170,000	1,170,000	645,000	531,000

	RAW WASTE		ANAEROBIC PROC. EFFLUENT		POND EFFLUENT CORRECTED FOR SEEPAGE	
	PPM	LBS	PPM	LBS	PPM	LBS
BOD	1,381	16,220	129	1,517	26	304
SUSPENDED SOLIDS	988	11,610	198	2,325	23	268

	PER CENT REMOVAL			
	THROUGH ANAEROBIC UNIT	THROUGH PONDS	THROUGH ENTIRE PLANT	DIGESTER LOADING lbs/day/cuft
BOD	90.8	79.8	98.2	0.156
SUSPENDED SOLIDS	80.2	88.4	97.6	0.112

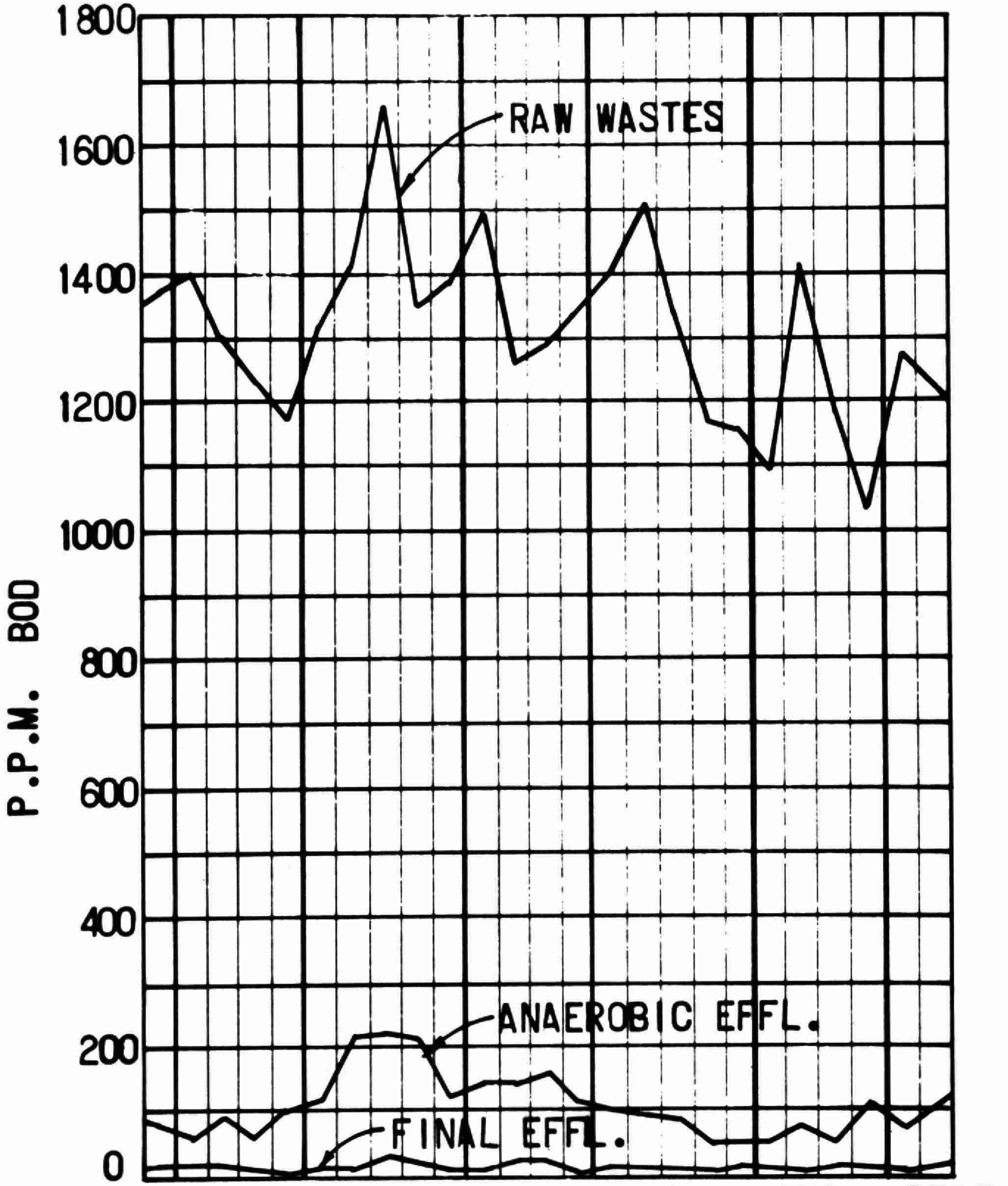

FIG. 4 -BOD DATA (WEEKLY AVERAGES)

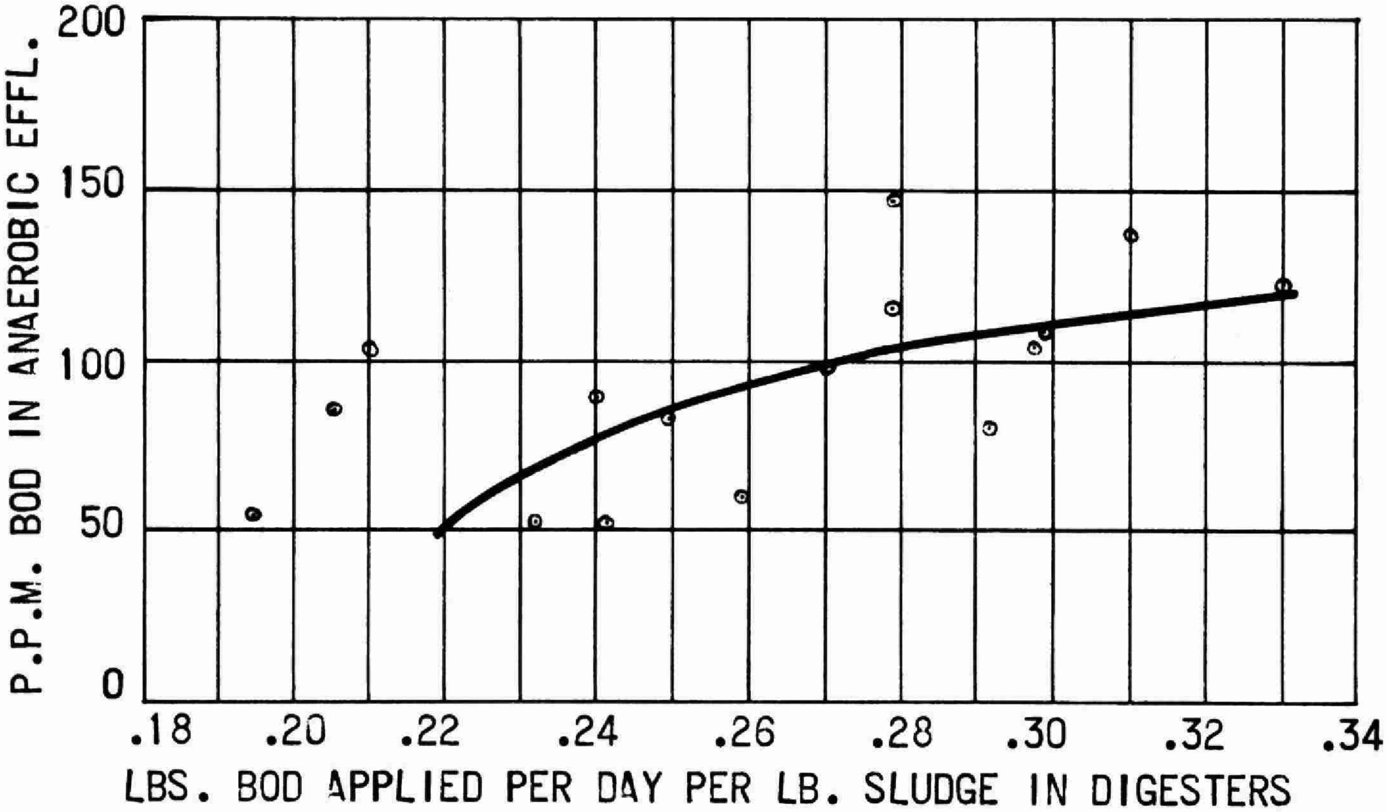

FIG.5 -- BOD APPLIED PER LB. SLUDGE VS. BOD IN EFFLUENT

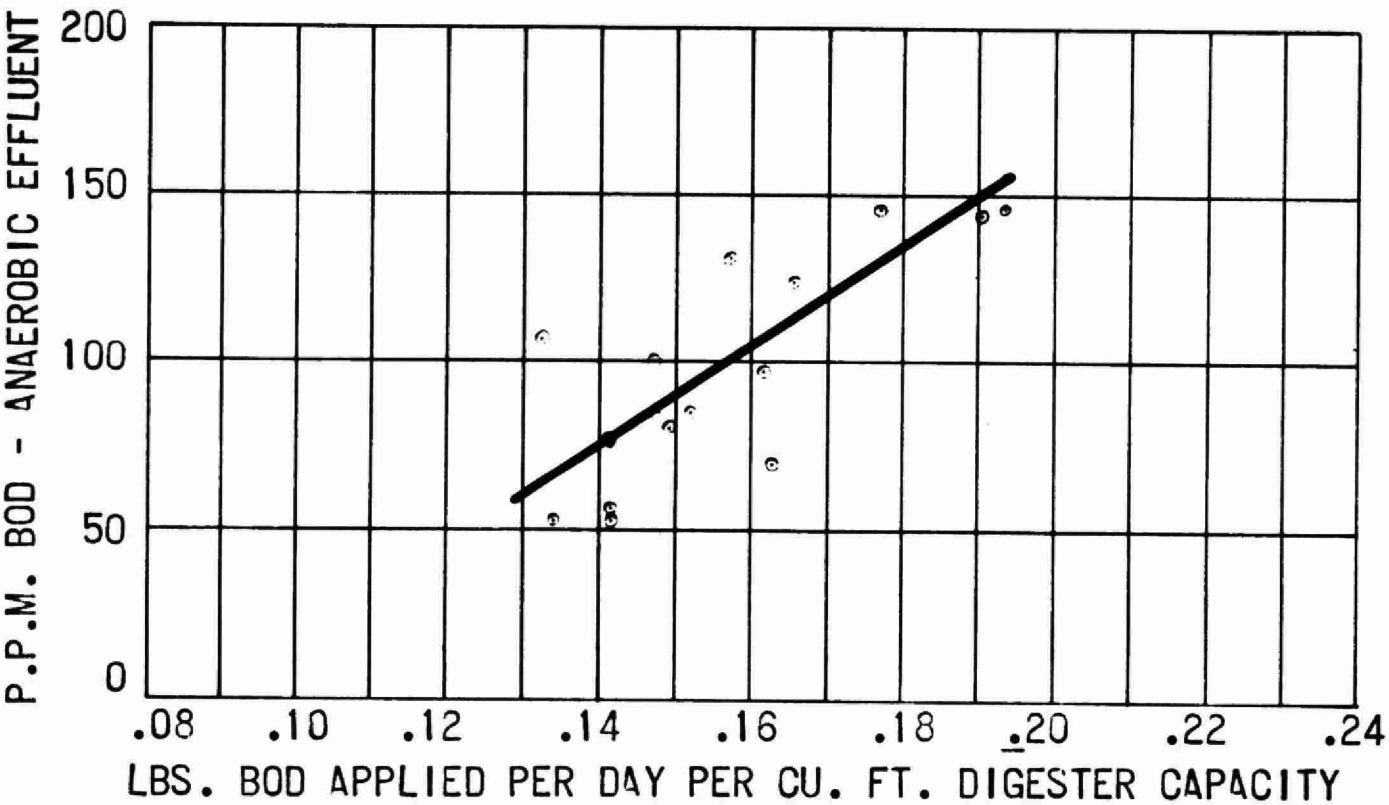

FIG.6--BOD APPLIED PER CU.FT. DIGESTER CAP. VS. BOD IN EFFL.

Disposal of raw meat packing wastes by irrigation has been successful in one installation in Illinois and one in New Zealand. Disposal of treated effluents by irrigation is more common and less spectacular. Some care is necessary to avoid high sodium concentrations to prevent soil damage. Further studies should be conducted to determine suitable crops and to research the possibility of disease transmission from feeding the irrigated crops to livestock.

Pond Systems

Anaerobic ponds serve successfully as "roughing" ponds for meat packing wastes principally because these wastes are warm (82° to 86°F), have high BOD and organic solids concentrations, and provide proper nutrient balance. These ponds are generally about 12 to 16 ft. deep and, at average loadings of 12 to 15 lbs. BOD per 1000 cu. ft., require far less land area than aerobic stabilization lagoons. Sludge is often recirculated to the inlet to seed the raw wastes. Because aerobic ponds can accept anaerobic effluents at high BOD loadings without upset, combinations of anaerobic ponds with various arrangements of aerobic ponds have become popular. However, pond systems treating meat industry wastewaters should be located with due regard to odour problems.

Anaerobic Contact Process

This process can remove 90 to 96% of the BOD in a waste of 1400 mg/l, at a digester loading of 0.16 lbs/day/cu. ft., with equalized flow. The digester is a completely mixed system and the mixed liquor is degasified by vacuum before gravity separation of sludge, which is returned to the digesters at ratios ranging between three and four to one. The process can be shut down on weekends and for extended periods without loss of treatment efficiency.

The anaerobic effluent can be further treated in conventional trickling filters, activated sludge plants or aerobic pond systems without difficulty.

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TECHNICAL SESSIONS

"CORN WET MILLING WASTES - METHOD OF CONTROL & TREATMENT"

BY

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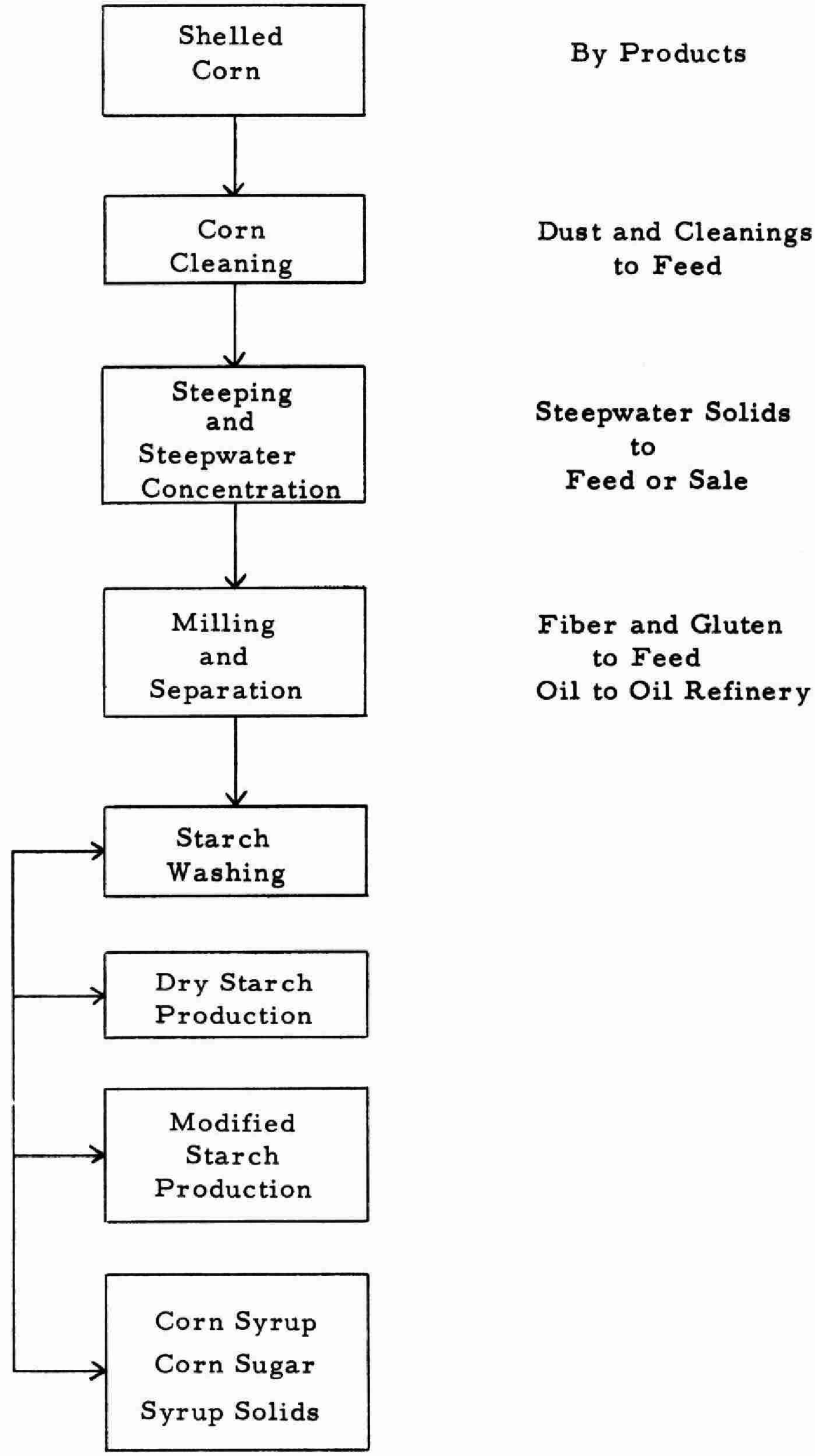
Starch is produced from a variety of grains and tubers, but in the United States corn is the predominant raw material. The process used for the production of essentially pure starch is known as the wet milling process and thus the industry is known as the Corn Wet Milling Industry. There are ten such companies in the United States with fourteen plants. In 1965, this industry processed approximately 200 million bushels of corn. From economic necessity, most of these plants are of large capacity.

The primary objective of the industry is to isolate the starch from the corn kernel. It is a complex process to accomplish this separation of the kernel into its component parts and attain maximum yields and high quality in the finished products. A very simplified flow sheet for the process is shown in figure #1.

The cleaned shelled corn is steeped for 36 to 44 hours in warm water which contains a small amount of sulphur dioxide. The latter retards fermentation and the steeping process softens the kernel so it can be more easily separated into its various components. At the end of the steeping process, the steepwater contains most of the soluble protein and minerals of the corn kernel. This steepwater is drawn off and concentrated by evaporation.



CORN WET MILLING PROCESS

FIGURE #1

The steeped corn is put through a milling process which involves grinding, floatation, screening and centrifuging. The kernel is separated into four parts, namely the germ, the fiber, the gluten and the starch. The germ which contains the oil is washed free of starch, dried, ground, and the oil removed by expellers or extraction. The residue that remains is known as the corn oil meal and is used for feedstuff.

The fiber is separated from the gluten and starch by a series of screening operations. It is mixed with the concentrated steepwater and also used for feedstuff.

The gluten or protein fraction is separated from the starch by centrifuging. It is concentrated, dried and sold as feedstuff.

The starch is further purified by a series of washings to free it from solubles. Fresh water enters the process only for washing the starch in the final stages of the operation. The filtrates from these fresh water washings are used over and over countercurrently in the operations. They eventually are used as the water for steeping the corn. They leave the process as the concentrated steepwater. In an ideal system the water will be used as many as nine times as shown in figure 2. This is the so-called "bottle-up process" which was developed years ago for this industry and is generally used in all the plants. Through this bottled up process it is not uncommon for the plants to attain a 99% recovery of the corn dry solids.

The purified starch can be dried and used in commerce as such. However, a major portion of it is further treated by chemicals to make a large variety of modified starches or converted to corn syrup, corn sugar or corn syrup solids.

Theoretically, there should be no losses from the process other than for entrainments in the concentration of the steepwater and the corn syrup. This is not the case as losses do occur and most of them are from the following sources:

1. - Unbalance of the complex water flow system.
2. - Leaks and spills.
3. - Errors in operations.
4. - Equipment malfunction.

DEGRADATION OF WATER (EXAMPLE)

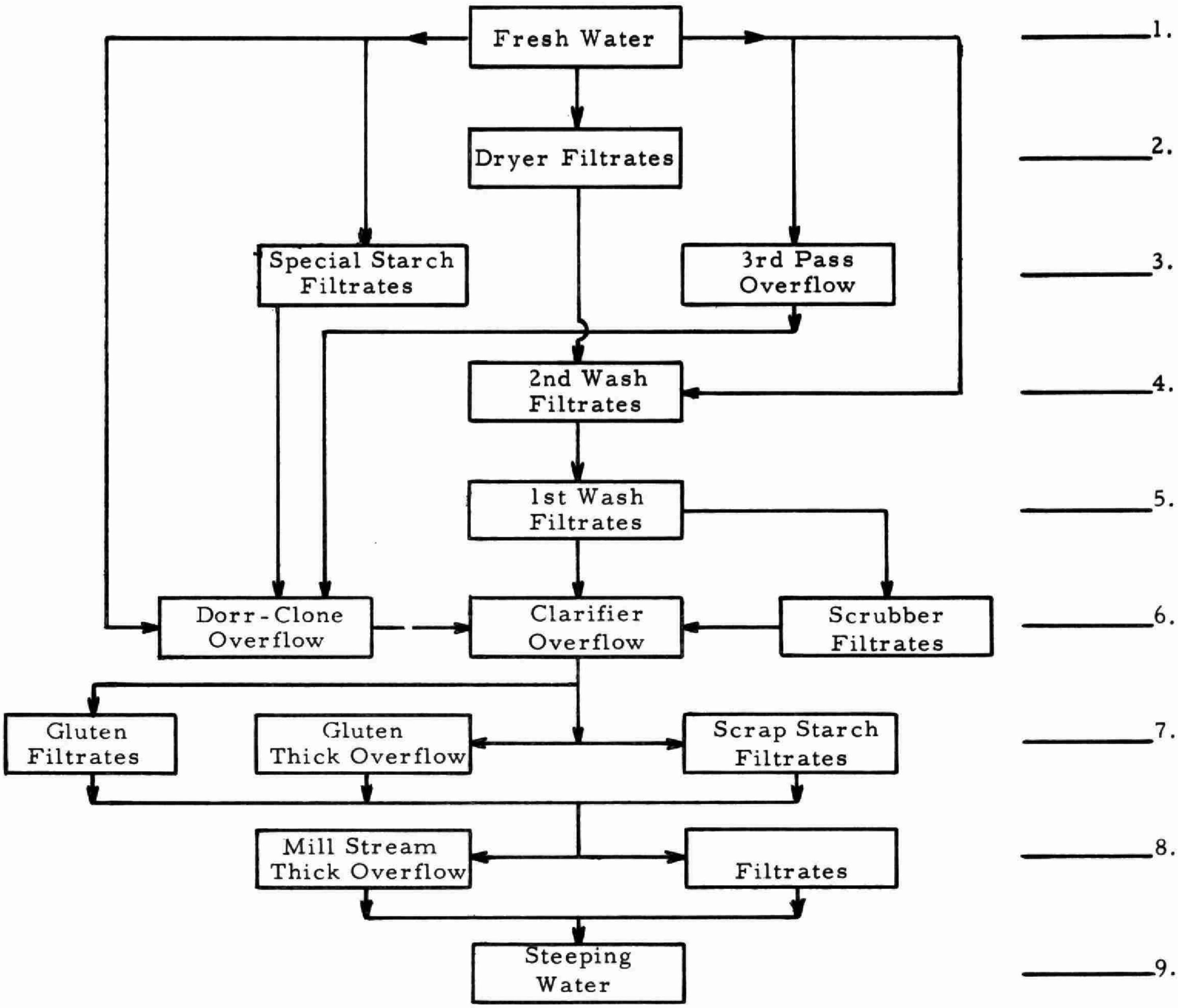


FIGURE #2

5. - Clean up from equipment and floor washings.
6. - Wash waters from modified starches which cannot be returned to the process.
7. - Entrainments from the evaporators.

In general, the wastes are very dilute suspensions of solids in water plus a high proportion of dissolved substances extracted from the raw materials. They consist mainly of nitrogenous compounds, carbohydrates and organic acids. These wastes lend themselves readily to all putrefactive and fermentation reactions. Thus, they are responsive to almost any complete disposal method that can be used for domestic sewage.

Up until the recent years, the plants separated the more concentrated wastes from the dilute wastes. The concentrated wastes were either partially treated or sent untreated to municipal treatment plants. The dilute wastes were disposed of by dilution in streams. Since recent State and Federal legislation make it prohibitive to dispose of these wastes to streams, the plants are being forced to change their methods of disposal.

Because some municipal treatment plants are unable to handle these wastes or where the charges are very high, a few of the corn processing plants have their own treatment facilities. Most of the plants, however, are working with the municipal authorities and at a cost are sending their wastes to the municipal treatment plants.

All the corn wet milling plants have active waste abatement programs and emphasize water conservation. Every effort is being made to contain the wastes within the process and various means are being studied for in-plant treatment.

The American Maize-Products Company is located in Hammond, Indiana, which is in the extreme northwest corner of the State. The plant is approximately 2,000 feet from the south shores of Lake Michigan. We process approximately 60,000 bushels of corn per day. We pump an average of 11 million gallons of water from the lake each day of operation and return to the lake as cooling water an average of 9 million gallons. The 2 million gallons that are retained are treated in our water treatment department and used by our power department and in the process.

Prior to 1940, the excess process waters were

mixed with the cooling waters and returned to Lake Michigan. In 1944, we started an intense waste abatement program. The waste waters were separated from the cooling waters. Sanitary sewage facilities were made available to the plant. A separate sewer system was built and all sanitary sewage and a limited volume of waste waters were sent to the municipal treatment plant. We have isolated and are treating approximately one million gallons of waste waters per day. They consist of the following:

1 - Condensate from the evaporation of steepwater. Surface condensers are used on the evaporators	300,000 gals.
2 - Syrup refinery process wash water, floor washings and some condensates	280,000 gals.
3 - Starch wash waters that contain chemicals that prevent re-use for food processing	100,000 gals.
4 - Excess process water that we are unable to concentrate at certain times	30,000 gals.
5 - Miscellaneous waters such as floor washings, surface drainage, roof drains, boil-out water from evaporators, and a small quantity of cooling waters	190,000 gals.

These waste waters are pumped to a three-stage lagoon system for treatment. The lagoon consists of two anaerobic sections followed by an aerobic section. The total area is approximately 10 acres with a holding capacity of 15 million gallons and a retention time of 15 days.

	Section 1	Section 2	Section 3
	anaerobic	anaerobic	aerobic
	(Inlet)	(Intermediate)	(Outlet)
Area	0.5 acres	2 acres	7.5 acres
Depth (average)	9 ft.	8 ft.	5 ft.
Capacity (gallons)	1 million	4 million	10 million
Retention time	1 day	4 days	10 days

You might ask, why did we elect to use a lagoon system for treating the wastes. Prior to 1950, we were able to re-use most all of the waste waters back in the process. However, there were some wastes, small in volume but high BOD, which could not be re-used. They consisted of such waters as "boil-out" from the evaporators, starch filtrates that contained chemicals that prevented re-use, wash waters from press clothes, etc. We were fortunate in having 10 acres of swamp land on our property. We diverted these waters to the swamp until we could find some method of disposing of them. Research showed they could be treated by the conventional activated sludge process. While this work was going on the swamp filled up and some of the water had to be diverted to the sewer. We were somewhat surprised to find there was an 80% reduction in the BOD. After a six month study, we elected to convert the swamp to a lagoon and treat the waste waters by this method. It so happened that about this time we started a modernization and expansion program in the plant. Several older brick buildings were demolished and this material was used for building a road through the swamp. This enabled us to clear the swamp of bullrushes and debris. We intended to operate it as an aerobic lagoon but the inlet section persisted in going anaerobic. The analysis showed we were getting very good reduction in the anaerobic section.

As might be expected, we encountered a number of difficulties in the operations during the first two years. First there was the problem of odours. The addition of sodium nitrate and the raising of the pH of the inlet waters seemed to solve this problem. During the summer months we attained a BOD reduction of over 90%. During the winter months this dropped to less than 20%. Our analysis showed that over 60% of the BOD reduction took place in the inlet section of the anaerobic area. The installation of a styrofoam blanket in this area has enabled us to maintain

the temperatures in the inlet section and thus a good reduction during the winter months.

Recycling of the waters on the anaerobic section is also helpful in obtaining a better reduction in the BOD. We recycle about 200,000 gals. per 24 hrs.

In 1964, we fouled up the operations by allowing too many suspended solids to enter the lagoon. We were modernizing the syrup refinery, and in this process changed from the use of bone char-vegetable carbon for bleaching the syrup to an all vegetable carbon system. During the period we elected to send a portion of the spent carbon to the lagoon rather than curtail the syrup refinery operations. As a result the inlet section of the lagoon, most of the area covered by styrofoam, was filled with insoluble solids. This resulted in an expensive cleaning operation and a marked lowering in the efficiency during the winter of 1964-1965.

In the cleaning operations, we built a permanent dam in the anaerobic section about 400 feet from the inlet. We had a definite purpose in mind in this project. First, to facilitate the cleaning of the inlet section and second, to study the effect of mechanical aeration in the second or intermediate anaerobic section. Indications are that one can attain increased efficiency by this addition aeration. It should also help to reduce some of the odours.

We had used a 25 h.p. aerator in the inlet section of the aerobic section. It was a floating type aerator and could not be used during the winter months since the aerobic section froze. This unit was moved to the intermediate section in January, 1966. Although we did not have any severe weather, the atmospheric temperatures were below freezing. The unit operated without difficulty and we have two more 25 h. p. on order for installation in this area.

The anaerobic lagoon does have its characteristic repulsive odour. The degree to which it can be reduced will probably depend on the users and their dedication to odour minimization. We have been able to reduce it to a low level by controlling the pH and the use of ammonium nitrate. In the early stages of the operation, we found we could reduce the odours and also get better reduction of the BOD by raising the pH of the inlet waters. We add an average of 20 gallons of 50 Bé caustic soda per hour. This raises the pH to a range of 8.0 to 10.0 and as a result, the pH of

the water leaving the anaerobic section is maintained in the 6.8 to 7.2 range.

We also found that the addition of sodium nitrate helped to reduce the odours. There was some question as to the effect of too much sodium with the use of caustic soda and sodium nitrate. The substitution of liquid ammonium nitrate for the sodium nitrate seems to be more beneficial. This is metered into the inlet waters from a pressurized tank car at the rate of one ton of ammonium nitrate per day. We are in the process of setting up a pilot plant project to make a more thorough study of the benefits of using ammonium nitrate.

In order to help minimize the odours since there is a residential area in the vicinity of the lagoon, we have installed an atomizing system for dispersing deodorants to mask the odours. There is a question as to the benefits of this operation but it does seem to be helpful.

Because of its peculiar evolution from a natural swamp to a controllable lagoon, the construction costs are rather difficult to determine. Much of the materials, such as pumps and piping, were taken from salvage and installed at labour costs only. We estimate we have about $200,000 invested in the project.

We can give you a fairly accurate report on the costs of operations. Table #1 gives the 1965 operating costs for this lagoon system.

L A G O O N   O P E R A T I N G   C O S T   1 9 6 5

Table #1

I. SALARIES (1/3 of total Industrial Waste)

3 Men	1 Jr. Chemist	)	
	1 Sr. Technician	)	$ 9,566
	1 Jr. Technician	)	

+ Fringe Benefits @ 16.3%

II. CHEMICALS

Liquid Caustic Soda 2,019,810 lbs.	$35,084
Ammonium Nitrate 814,740 lbs.	25,251

Polycide 974-A 715 gallons	$ 2,251	
Total Chemicals		$ 62,586

III. MAINTENANCE SERVICES

Labour	$25,887	
Materials	6,941	
Total Maintenance Services		$ 32,828

IV. ELECTRIC POWER

Constant use of 64.5 h.p. x 0.75 x 24 hrs.
x 365 days = 423,765 KWH
423,765 KWH @ 5.482/M = $ 2,323

V. FIXED CHARGES

Depreciation	$ 1,995	
Taxes	699	
Insurance	64	
Total Fixed Expense		$ 2,758
Total Annual Operating Cost		$110,061

From the yearly costs we can arrive at the approximate unit cost for the treatment in 1965 as shown in

Table #2

BOD Loadings to Lagoon (daily average)	3313 ppm
BOD Loadings from Lagoon (daily average)	835 ppm
BOD Reduction	2478 ppm
BOD Reduction	74.5%
Volume Waste Water treated per day	1.064 M.G.D.
Pounds BOD removed per day	22,188
Pounds BOD removed per year	8,198,620

Cost of operations for year 1965	$	110,061
Cost per day		302
Cost per 1000 lbs. BOD removed	$	13.61
Cost per million gallons Waste Water treated		284.00

In summary, we can say that the wastes from the Corn Wet Milling Industry can be treated by the conventional methods used for domestic wastes. The lagoon system is quite satisfactory with the exception of available space required and possibly odours. The big advantages are: it can handle a wide variation in quality and quantity of wastes with little loss in efficiency. Also, it requires a minimum of manpower and maintenance.

We like to think of it as a "poor man's activated sewage plant."

Tables 3, 4, 5 and 6 show the benefits derived from the addition of styrofoam cover.

Tables 7, and 8 show the results we obtained with the lagoon for 1965.

ANAEROBIC LAGOON TEMPERATURES - JANUARY 1963

(Temp. = 0°F.)

Date	Anaerobic Inlet Temp.	COVERED AREA - TEST STATIONS #1	#2	#3	#4	#5	#6	#7	#8	Temp. Drop #1 to #8	Anaerobic Outlet	Air Temp.
1/ 1/63	90°	88°	89°	88°	78°	78°	74°	62°	66°	22°	63°	31°
1/ 4/63	89°	91°	91°	91°	84°	78°	72°	71°	69°	22°	61°	31°
1/ 8/63	99°	97°	97°	97°	94°	88°	84°	82°	81°	16°	63°	40°
1/ 9/63	87°	93°	93°	93°	89°	87°	83°	80°	76°	17°	70°	45°
1/14/63	93°	82°	82°	82°	70°	65°	60°	60°	60°	22°	52°	7°
1/15/63	91°	94°	94°	94°	83°	83°	70°	65°	65°	29°	53°	-2°
1/16/63	96°	94°	94°	94°	85°	83°	78°	72°	68°	26°	54°	4°
1/30/63	93°	94°	94°	92°	87°	85°	85°	84°	75°	19°	46°	10°
Average	92°	91°	91°	91°	83°	81°	76°	72°	70°	21°	58°	21°

TABLE #3

ANAEROBIC LAGOON TEMPERATURES - SUMMARY
October 1962 - September 1963
(Temp. = 0°F)

	Anaerobic Inlet Temp.	COVERED AREA - TEST STATIONS #1	#2	#3	#4	#5	#6	#7	#8	Temp. Drop #1 to #8	Anaerobic Outlet Temp.	Air Temp.	% B.O.D. Reduction Anaerobic Section
OCT.-62	108°	90	89	82	80	77	75	-	-	-	75	43	82.4%
NOV.-62	101°	87	87	87	83	81	79	77	75	12	67	46	69.0%
DEC.-62	91°	93	93	93	88	82	77	72	72	21	56	40	73.5%
JAN.-63	93°	91	91	91	83	81	76	72	70	21	58	21	60.3%
FEB.-63	90°	84	84	84	78	78	77	73	71	13	60	31	58.0%
MAR.-63	93°	89	82	79	76	75	74	73	72	17	62	48	60.1%
APR.-63	110°	97	97	94	87	85	84	84	83	14	68	61	71.8%
MAY -63	113°	102	103	99	94	92	91	88	87	15	77	64	83.3%
JUNE-63	114°	106	105	102	101	100	99	98	97	9	90	80	90.5%
JULY-63	114°	105	105	103	103	103	102	100	100	5	89	83	90.6%
AUG.-63	113°	106	106	105	105	103	102	101	100	6	89	78	92.1%
SEPT.-63	113°	100	100	100	100	100	99	99	97	3	90	80	92.6%
Average	104°	96	95	94	90	88	86	85	84	12	73	56	77.0%
JAN.-61	91°	66	-	-	-	-	-	-	-	-	51	7.5	
FEB.-62	92°	65	63	57	55	54	-	49	49	-	49	6.4	

TABLE #4

B.O.D. REDUCTION - ANAEROBIC SECTION

Covered vs. Uncovered

UNCOVERED

		B.O.D. Water to Anaerobic Section	B.O.D. Water From Anaerobic Section	Reduction in B.O.D.	% Reduction in B.O.D.
OCT.	- 61	1660	702	958	57.7
NOV.	- 61	2441	1092	1349	55.2
DEC.	- 61	2878	1376	1502	52.1
JAN.	- 62	2305	1805	500	21.7
FEB.	- 62	1906	1784	122	6.4
MAR.	- 62	2456	1322	1134	46.2
APR.	- 62	2160	982	1178	54.6
MAY	- 62	2572	715	1857	72.2
JUNE	- 62	2204	453	1751	79.4
JULY	- 62	2142	385	1757	82.0
AUG.	- 62	2596	414	2182	84.0
SEPT.	- 62	2012	362	1650	82.0
AVE.		2277	949	1328	58.3

COVERED

		B.O.D. Water to Anaerobic Section	B.O.D. Water From Anaerobic Section	Reduction in B.O.D.	% Reduction in B.O.D.
OCT.	- 62	2167	382	1785	82.4
NOV.	- 62	2256	699	1557	69.0
DEC.	- 62	2716	712	2004	73.8
JAN.	- 63	2661	1056	1605	60.3
FEB.	- 63	2732	1148	1584	58.0
MAR.	- 63	2469	985	1484	60.1
APR.	- 63	2578	728	1850	71.8
MAY	- 63	4123	690	3433	83.3
JUNE	- 63	4027	384	3643	90.5
JULY	- 63	3794	356	3438	90.6
AUG.	- 63	3931	310	3621	92.1
SEPT.	- 63	3517	258	3259	92.7
AVE.		3081	642	2439	77.1

TABLE #5

AMERICAN MAIZE-PRODUCTS COMPANY

INDUSTRIAL WASTE LAGOON

OVERALL EFFICIENCY - % B.O.D. REDUCTION

YEAR	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	AVE.
1960	4.4	13.0	3.1	24.0	30.0	57.0	68.0	85.0	80.0	82.0	57.0	32.0	44.6
1961	32.0	21.0	46.0	75.1	75.0	88.8	80.4	87.9	85.8	77.4	78.7	69.7	68.1
1962	37.9	25.8	61.6	73.2	91.6	95.0	94.0	94.3[a]	93.3[a]	92.5[a]	86.0	87.3	77.7
1963	64.6	60.2	72.2	84.3	91.2	97.3	96.8	97.2	97.8	98.1	96.0	88.1	87.0
1964	79.0	84.6	81.2	84.5	89.0	91.4	92.7	92.3	90.8	86.9	80.1	38.4[b]	82.6
1965	43.7[b]	31.5	26.4	56.2[c]	91.6	95.2	93.0	94.5	94.7	93.0	89.2	74.6	73.6
1966	73.6	79.1	83.0	85.4									

(a) Styrofoam Cover Installed
(b) Inlet Section Cleaned
(c) Styrofoam Cover Re-installed

TABLE #6

WATER TO LAGOON #29 (ANAEROBIC SECTION) 1965

Table #7

DATE	BOD ppm	BOD LBS.	COD ppm	COD LBS.	M.G.D.	TOTAL SOLIDS ppm	SOLUBLE SOLIDS ppm	pH	TEMP. °F.
Jan.	3819	25178	5954	39598	.7945	5936	4547	9.5	92
Feb.	3376	25151	4807	38249	.8935	5481	3888	9.7	91
Mar.	2858	21790	4671	35610	.9118	4481	3248	9.5	98
Apr.	2133	18307	3383	29684	1.0466	4124	3155	9.2	106
May	2510	19991	3904	31100	.9730	4387	3490	8.7	103
June	3631	33920	5855	54449	1.1209	5743	4304	8.9	112
July	2694	25701	4324	41279	1.1369	3977	2971	8.1	120
Aug.	3676	37629	5968	55808	1.1617	5614	4430	9.5	112
Sept.	3926	40954	6305	65807	1.2476	5296	3847	7.9	113
Oct.	4239	42638	6606	66413	1.1975	6060	4552	9.4	104
Nov.	3515	34840	5869	60047	1.2225	5423	4468	9.6	95
Dec.	3374	31133	5565	48696	1.0590	5684	4591	9.0	95
AVE	3313	29769	5268	47228	1.0638	5184	3958	9.1	103
MED	3376	25701	5565	41279	1.0590	5423	3888	9.2	103
HIGH	4239	42638	6606	66413	1.2476	6060	4591	9.7	120
LOW	2133	18307	3383	29684	.7945	3977	2971	7.9	91

WATER FROM LAGOON #30 (AEROBIC SECTION) 1965

Table #8

Jan.	2148	20273	3702	35023	1.1417	3485	3274	6.9	46
Feb.	2313	19227	4046	33739	.9428	3932	3683	5.9	45
Mar.	2104	18345	3708	32262	1.0638	3274	3156	6.0	48
Apr.	934	7872	1653	14015	1.1667	2511	2354	8.2	61
May	211	2301	385	4170	1.0908	1658	1596	8.4	71
June	175	2255	381	5021	1.5695	2004	1904	7.8	76
July	187	1117	394	2402	.6317	1641	1556	8.2	82
Aug.	201	2646	477	6452	1.6476	1810	1781	8.3	78
Sept.	207	2218	491	5189	1.2327	1914	1816	8.3	73
Oct.	298	4192	603	8149	1.6507	2070	1974	8.2	60
Nov.	381	3374	733	6333	1.1080	1942	1859	8.2	49
Dec.	856	7155	1642	13299	.9484	2558	2385	8.1	41
AVE	835	7581	1518	13838	1.1829	2400	2278	7.7	61
MED	298	3374	603	6452	1.1080	2004	1904	8.2	60
HIGH	2313	20273	4046	35023	1.6476	3932	3683	8.4	82
LOW	175	1117	381	2402	.6317	1641	1556	5.9	41

"LABORATORY APPROACHES TO THICKENER DESIGN"

by

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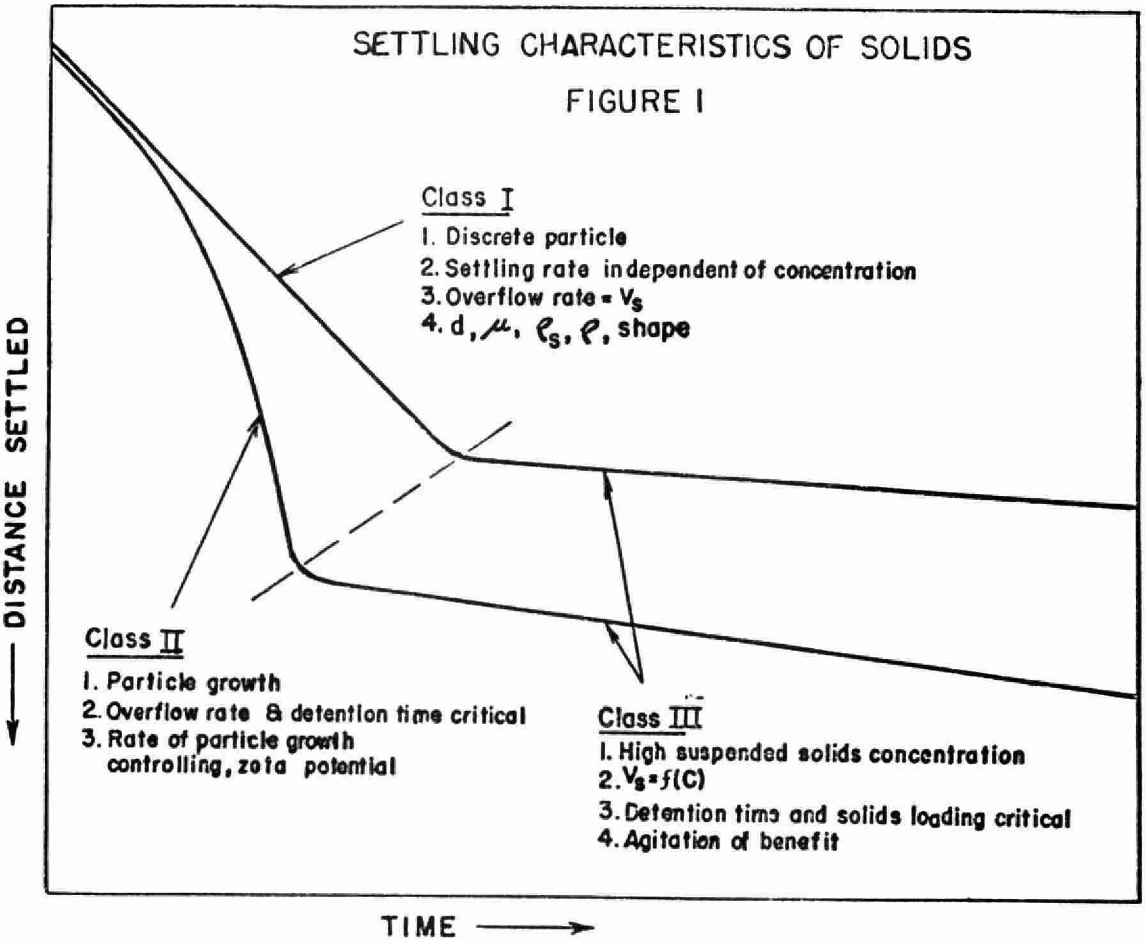
The removal of solids dispersed in liquid wastes and the subsequent thickening of the resultant underflow by gravity separation is a well established process. Because of the practical importance of sedimentation, it has been the subject of extensive studies but no comprehensive theories or empirical formulae have been derived to enable a designer to proceed with confidence without recourse to experimental studies coupled with excessive factors of safety. The hydrodynamics of a single spherical particle in an infinite media can be described by Stokes' relationships. Subsequent formulations by other workers have extended these relationships to particle swarms when the density of the particles is small and the distance between particles is considerably greater than their effective diameter.

Particulate suspensions may be arbitrarily divided into classes on the basis of their settling characteristics. The characteristics of these classes are presented in Figure 1. Class I & II particles, at low concentrations, settle individually at velocities determined by the individual particle characteristics. During the settling process classification normally will occur, caused by the differences in settling velocities. If the particles are closely sized a distinct interface will develop even at low concentrations. While the proximity of the wall and other particles will affect



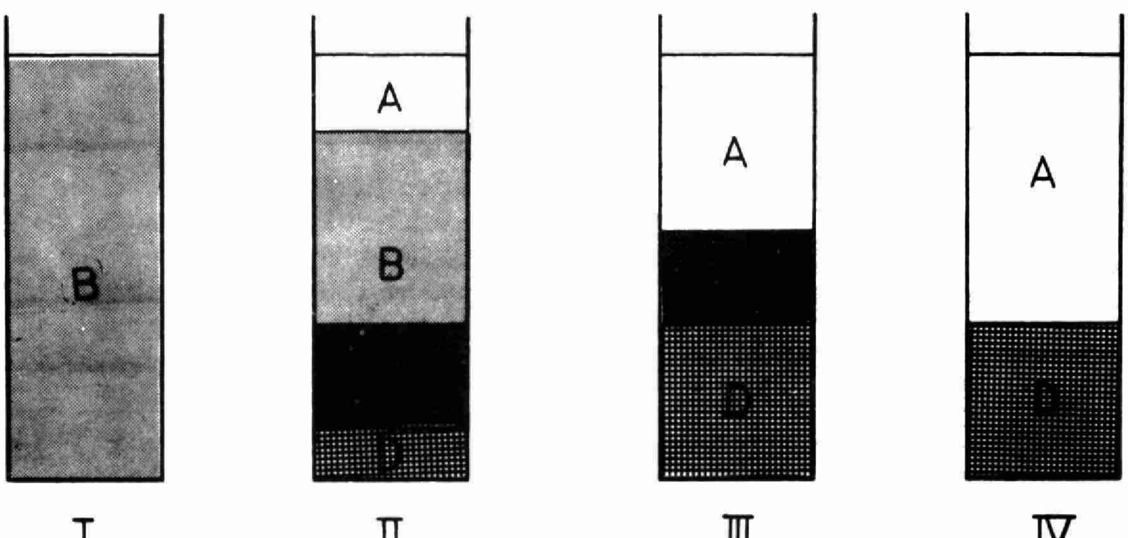


FIG. 2 ZONE FORMATION IN HINDERED SETTLING

the settling rates, the rate will be in the same order of magnitude as the predicted Stokes' velocity for the particle. With class III particles the high concentration will cause the slurry to settle with a sharp line of demarcation even when the individual particles differ greatly in character. In this "hindered settling" the particles or flocs are close together and because of particle interaction the settling velocity is governed by the characteristics of the suspended mass.

One of the earliest studies, on the hindered settling of slurries, was the batch-test data presented by Coe & Clevenger (1916). Figure 2 presents schematically the observed results when a slurry, initially of uniform concentration (B), was allowed to settle. As settling progressed, a zone of clarified liquid (A) developed at a rate which was proportional to the original concentration. Concurrent with the formation of the clarified zone, the solids at the bottom (D) were concentrated to a point where they were mechanically supported. Immediately above this compression zone, a zone of intermediate concentration (C) developed. During subsequent settlement, zones "A" and "D" increased in volume accompanied by the extinction of zone "B". Zone "C" moved upwards from the bottom in advance of zone "D" eventually dissappearing after contacting zone "A".

Subsequent workers including Comings (1940) and Work and Kohler (1940) added to the knowledge of the effects of various physical parameters on slurry settling. In 1952 Kynch (1952) published a comprehensive mathematical analysis of the process. This analysis was based on the assumptions that:

1. the settling velocity is dependent only on the local particle concentration,

2. the wall effects are insignificant, and

3. all particles settle at the same rate.

To simplify the mathematics other assumptions were introduced:

1. the particle concentration is uniform across any horizontal layer,

2. the initial particle concentration increases toward the bottom of the slurry, and

3. the settling velocity of the particles tend to zero as the concentration approaches the limiting value.

Kynch proved mathematically that in a batch test bands of intermediate concentration ($C_i < C < C_m$) are propagated upwards through the slurry from the bottom at a constant velocity. When these bands of intermediate concentration reach the interface the settling velocity of the interface will decrease giving rise to the typical curvilinear height-time interfacial settling curve (Figure 3). The initial linear subsidence (A-B) is a function of the initial solids concentration. As the bands of intermediate concentration reach the surface subsidence rate decreases (B-C) until the maximum concentration is reached. If the solids are incompressible no further subsidence will occur (C-D will be horizontal).

When the concentrated suspensions (Class III particles) are to be separated or thickened a successful design must consider

1. the clarification capacity or overflow rate, and

2. the thickening capacity or solids loading rate.

Consider a slurry of solids of concentration C_i fed continuously at a volumetric feed rate Q_i into an "ideal" cylinderical semi-continuous thickener with cross-sectional area A (Figure 4-1). If it is assumed the inlet distributes the slurry uniformly over the cross-section then the settling velocity of the feed slurry (u_i) must exceed the overflow rate of the unit ($u_i > Q_i/A$) if particulates are not to be present in the effluent (Q_i).

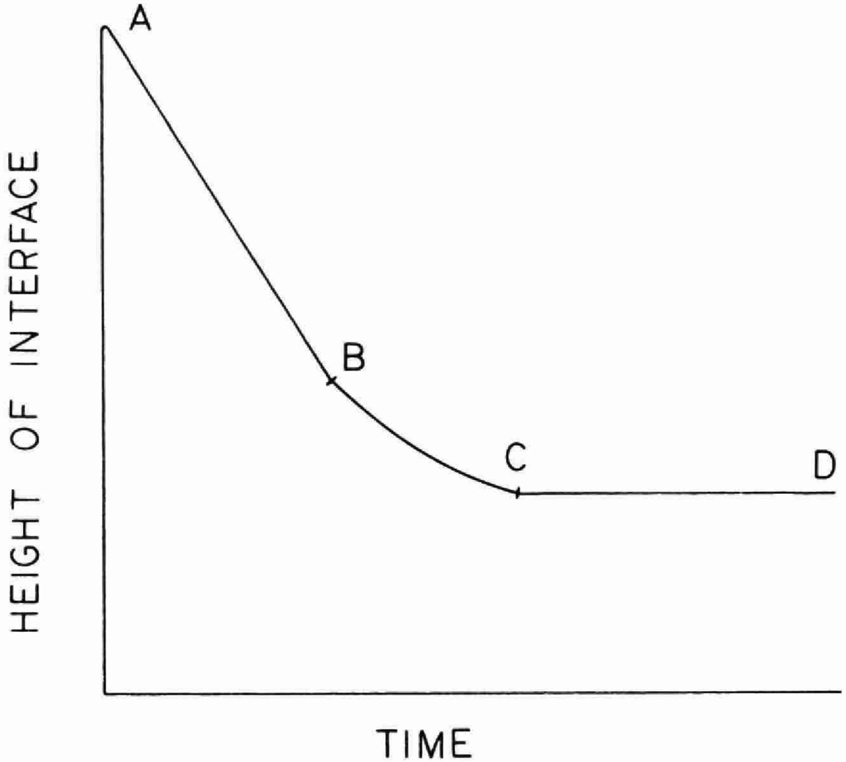


FIG. 3 INTERFACE SETTLING CURVE FOR HINDERED SETTLING

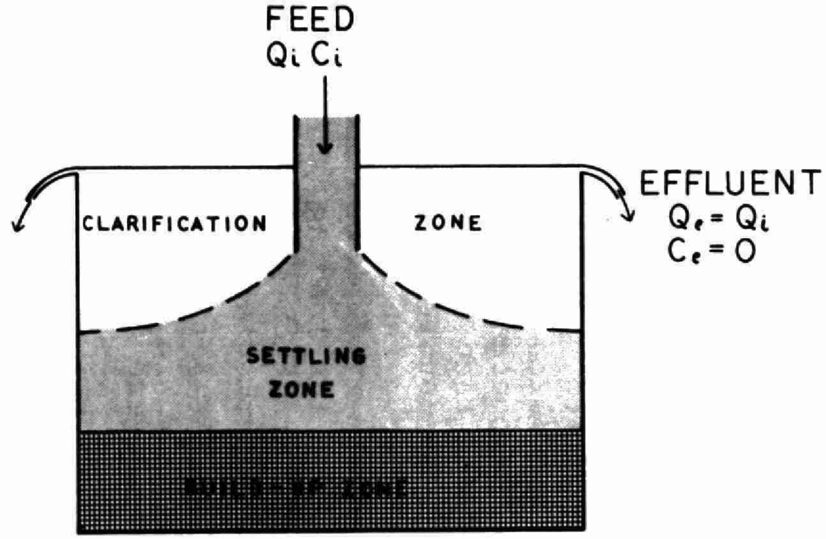


FIG. 4-1 SEMI-CONTINUOUS THICKENING

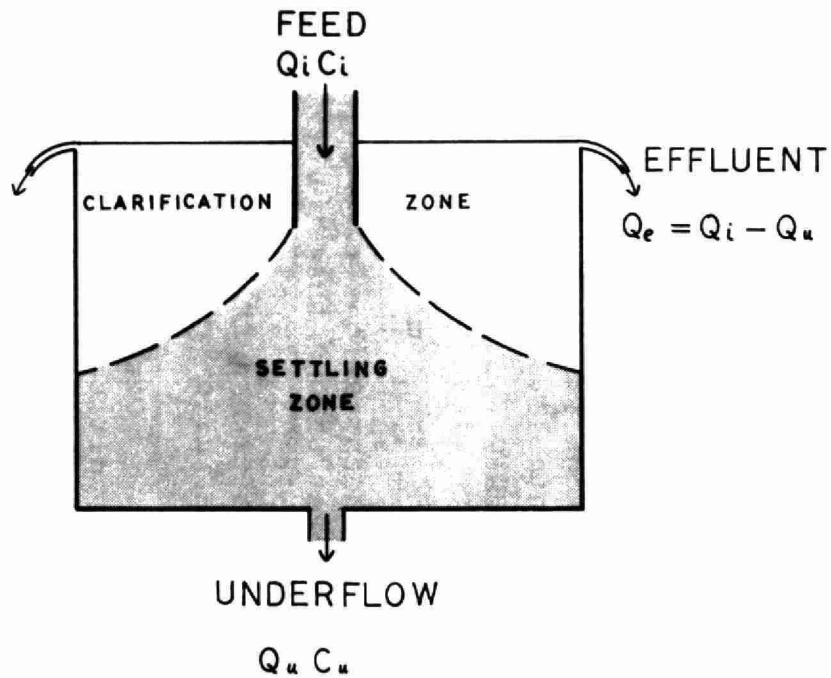


FIG. 4-2 CONTINUOUS THICKENING

If no carry-over of particles occurs then a settling zone will form below the inlet and will terminate in a zone in which the particles are supported mechanically, analogous to zone "D" in the batch test of Figure 2. Within the settling zone the concentration of particles (C) will vary from that of the feed C_i to the maximum (C_m) attainable under the given conditions or $C_i < C < C_m$. Since all particles must traverse the range of concentrations from initial (C_i) to maximum (C_m) concentrations then the mass flux (S) or solids loading rate per unit area cannot exceed the rate at which solids can be transported through any layer of intermediate concentration existing within the thickener.

With the continuous thickener (Figure 4-2) the conditions remain the same except a continuous underflow (Q_u) is discharged. Since an overall liquid balance must exist,

$$Q_i = Q_e + Q_u$$

then the presence of an underflow decreases the overflow rate increasing the clarification capacity ($u_i > Q_e/A$ or $Q_i - Q_u/A$). In addition to the settling of the solids within the slurry, exhibited in the semi-continuous thickener, there is a bulk downward movement equal to Q_u/A. This will allow a higher solids loading rate compared to semi-continuous thickening.

The total solids flux (S) results from two different phenomena, settling of the solids within the slurry, and the movement of the slurry relative to the vessel. Thus:

$$S = c \cdot u + c \cdot v$$

where: S = solids flux g/cm^2-min.,
u = settling velocity of the solids cm/min.,
v = velocity of the bulk slurry cm/min, and
c = concentration of the slurry g/cm^3.

In batch studies or semi-continuous thickeners the velocity of the slurry relative to the vessel is zero while with continuous thickening "v" is dependent upon

the operating underflow rate ($v = Q_u/A$). Batch studies can be used to determine the solids loading rates for various concentrations of slurries. Coe and Clevenger (1916) proposed a series of batch tests at various initial concentrations to obtain the relationship between solids flux and concentration. Talmage and Fitch (1955) presented a method of obtaining a flux plot from a single batch test at the anticipated feed concentration. With this procedure it was not necessary to assume that the settling characteristics are independent of the initial solids concentration from which they are formed. Subsequent studies (Shannon and Tory (1965) and Shannon et al (1963)) indicated the secondary effects, which cause only small deviations from expected curves based upon the concentration concept, could lead to large errors in constructing a flux plot.

The studies presented in the literature have dealt, mainly, with incompressible or slightly compressible inorganic slurries. Little data would appear to be available on the limitations of these techniques when applied to typical sludges from waste effluents. Mancini (1962) reported a study using pulped newsprint slurry to simulate waste activated sludge. As the variable character of typical activated sludge does not lend itself to the repetitive type of study needed to demonstrate the applicability of the laboratory testing procedures, it was decided to use pulped newsprint which while representative of organic slurries would allow extended periods of testing without significant changes in characteristics. The newsprint was weighed then wetted and blended at 15,000 rpm for 3 to 5 minutes. It was diluted to the required concentrations and allowed to stand in the test cylinders for 24 hours prior to the commencement of testing. This procedure combined with careful mixing seemed to provide reproducible results. The sludge volume index for a representative range slurry concentrations was 204 with a standard error of 23. With this S.V.I the slurry of pulped newsprint could be considered to have settling properties similar to "bulking" activated sludge. While a better settling slurry might be desirable it was felt that this was representative of the worst type of sludge normally produced by activated sludge treatment plants.

One of Kynch's basic assumptions in the

development of his mathematical model was the absence of wall effects. If Kynch's postulates are to be used it is necessary to select a cylinder which does not effect the settling properties of the suspension. A series of tests using Acrylic plastic test cylinders of 5 1/2, 9 and 14 cm inside diameter indicated no significant difference in settling characteristics for slurries ranging in initial concentration from 1.5 to 4.0 g/l (Figure 5). As no difference was detected the 9 cm column was selected for further use.

To construct a solids flux plot as outlined by Coe and Clevenger (1916) it is necessary to relate the solids concentration and the settling rate of the interface. Initial slurry heights from 37 to 240 cm (Z) were selected and the initial settling rates (u_i) were determined for initial concentrations (C_i) from 1.0 to 9.0 g/l. Typical settling curves obtained from 3 replicate tests are illustrated in Figure 6. In addition to the three zones characteristic of hindered settling there is an initial lag period in which little settlement occurs. This lag period varied with solids concentration, cylinder diameter, and height. This period has been ascribed (Mancini 1962) to residual turbulence from the initial mixing of the slurry. Other investigators have extrapolated the linear portion of the curve back to intersect the initial column height using the point of intersection as the zero time for the test. This was done in this study, the three replicates being used to define a single settling curve for the given initial height and solids concentration. Figure 7 illustrates settling curves obtained for 2.0 g/l initial concentration at different column heights. Using the 37 and 60 cm. columns no well defined linear portion of the settling curve was obtained. This suggests that intermediate concentrations have reached the interface before accurate measurements of interface height were obtained. Some slight variations in the linear initial settling rates were observed between the 120 and 240 cm. columns for some initial concentrations. It is possible that incomplete initial mixing could account for this variation as relatively small concentration changes are necessary to account for the observed differences.

If the slurry is "ideal" and the settlement

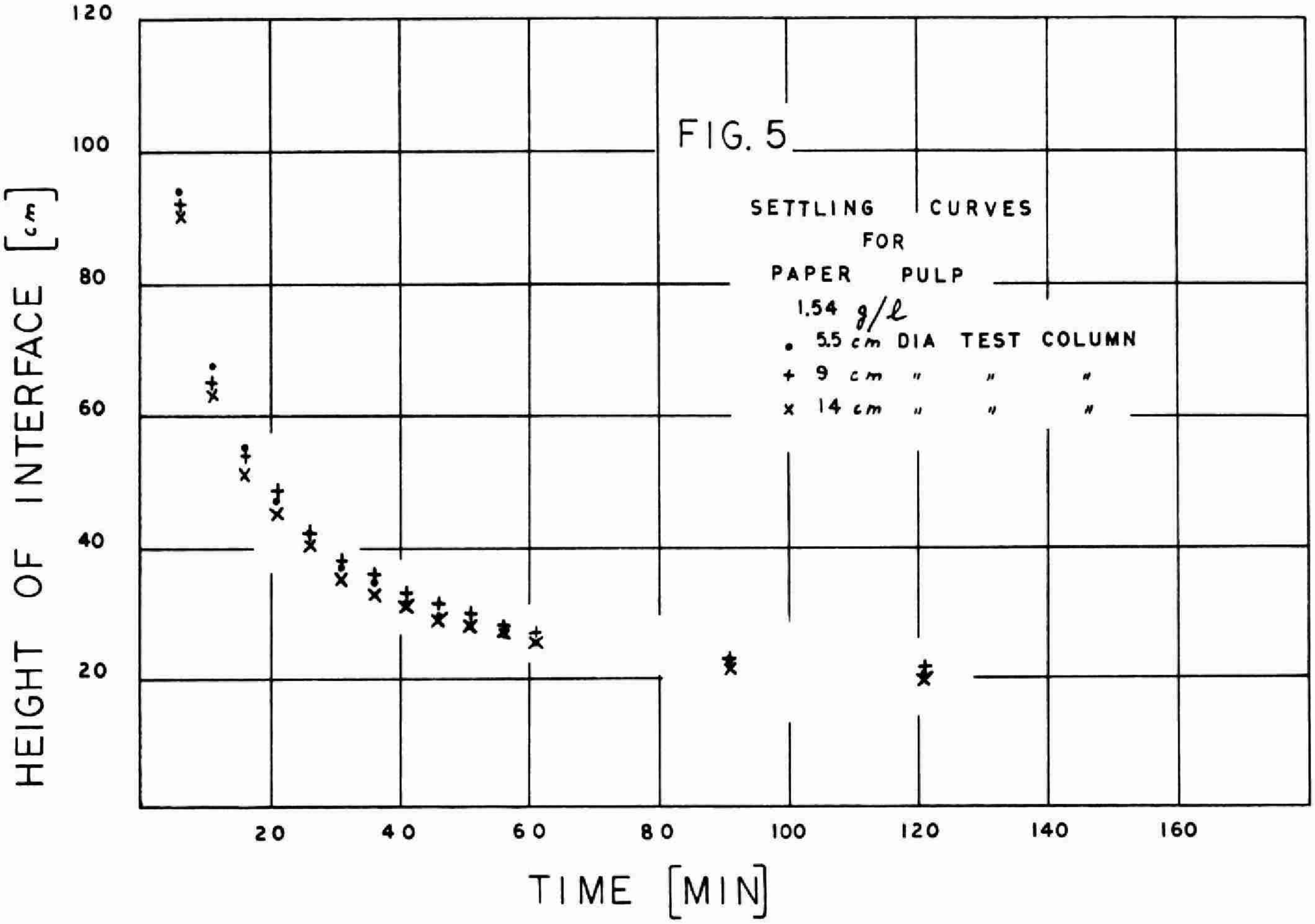


FIG. 5
SETTLING CURVES
FOR
PAPER PULP
1.54 g/l
• 5.5 cm DIA TEST COLUMN
+ 9 cm " " "
x 14 cm " " "
HEIGHT OF INTERFACE [cm]
TIME [MIN]
120
100
80
60
40
20
20
40
60
80
100
120
140
160

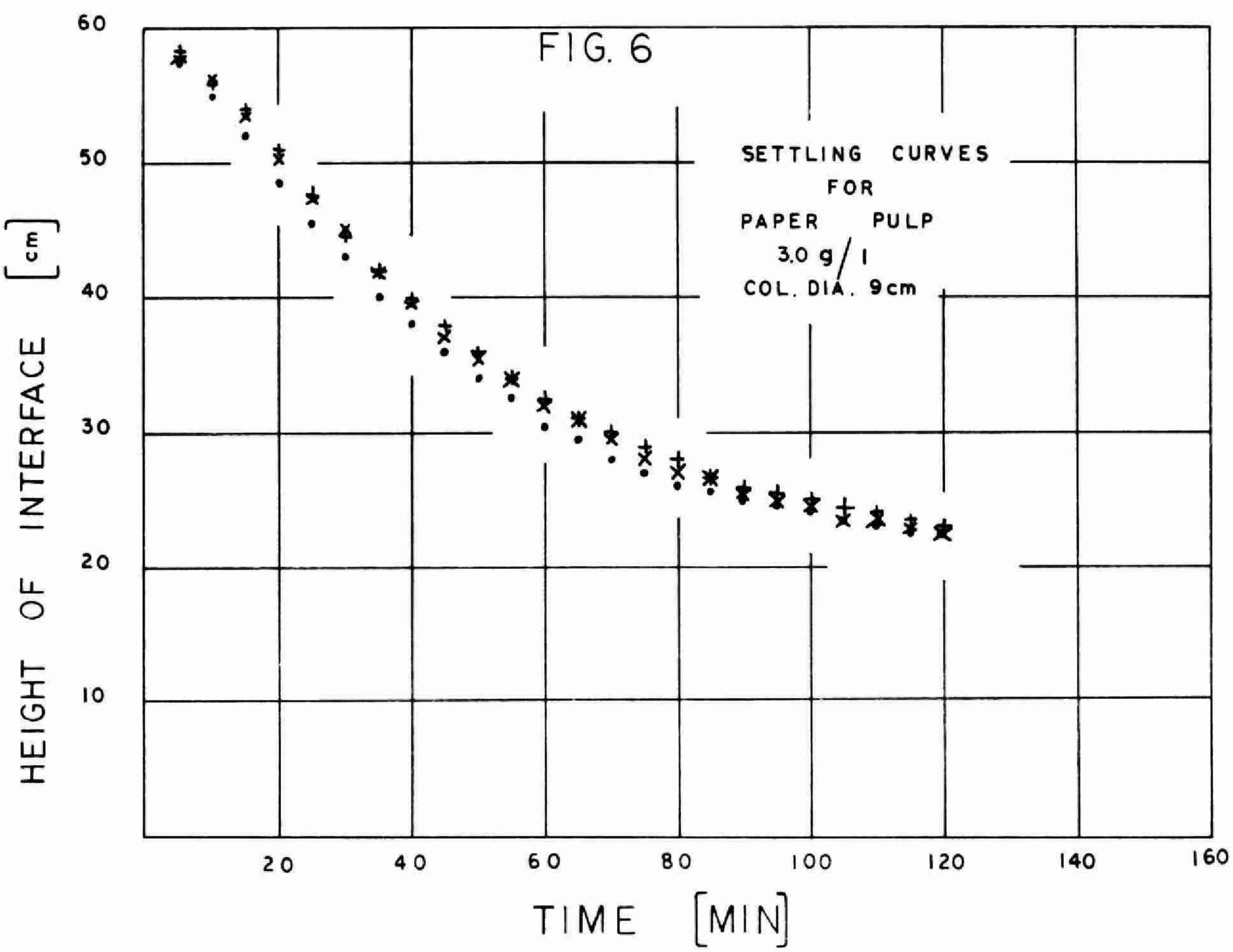


FIG. 6
SETTLING CURVES
FOR
PAPER PULP
3.0 g/l
COL. DIA. 9cm
HEIGHT OF INTERFACE [cm]
TIME [MIN]
60
50
40
30
20
10
20
40
60
80
100
120
140
160

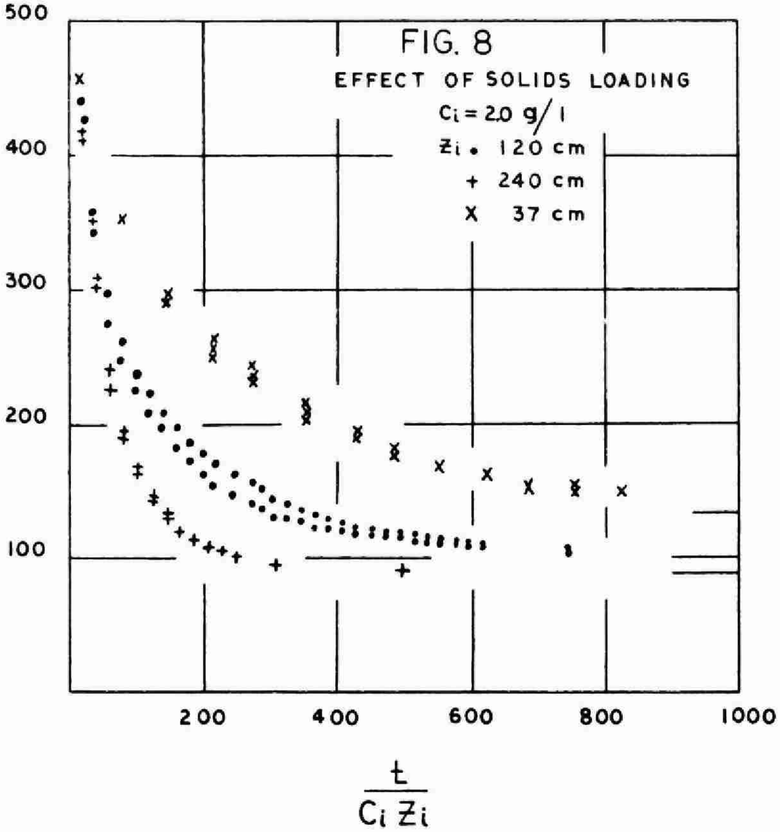


FIG. 8

EFFECT OF SOLIDS LOADING

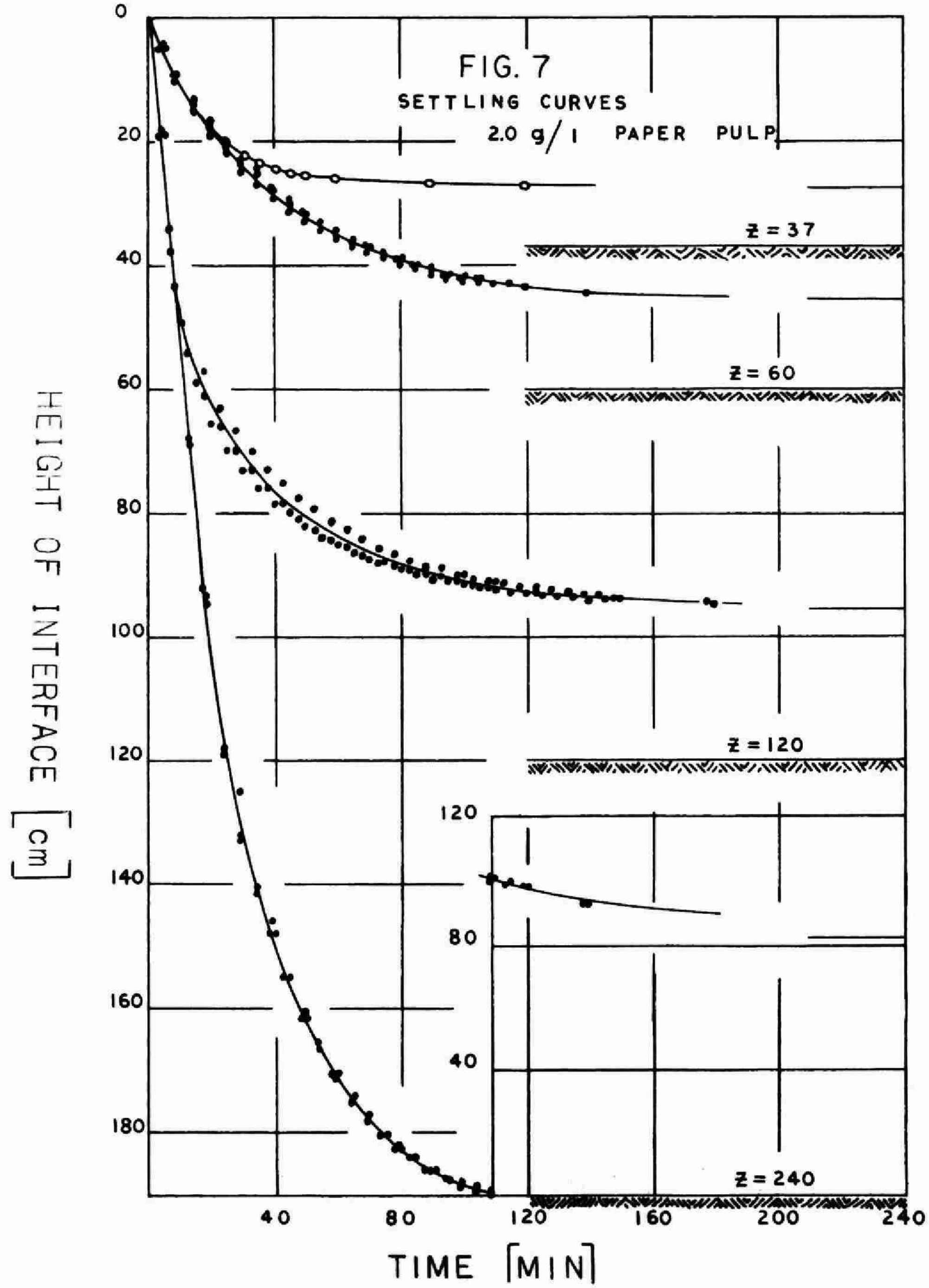


FIG. 7

SETTLING CURVES

2.0 g/l PAPER PULP

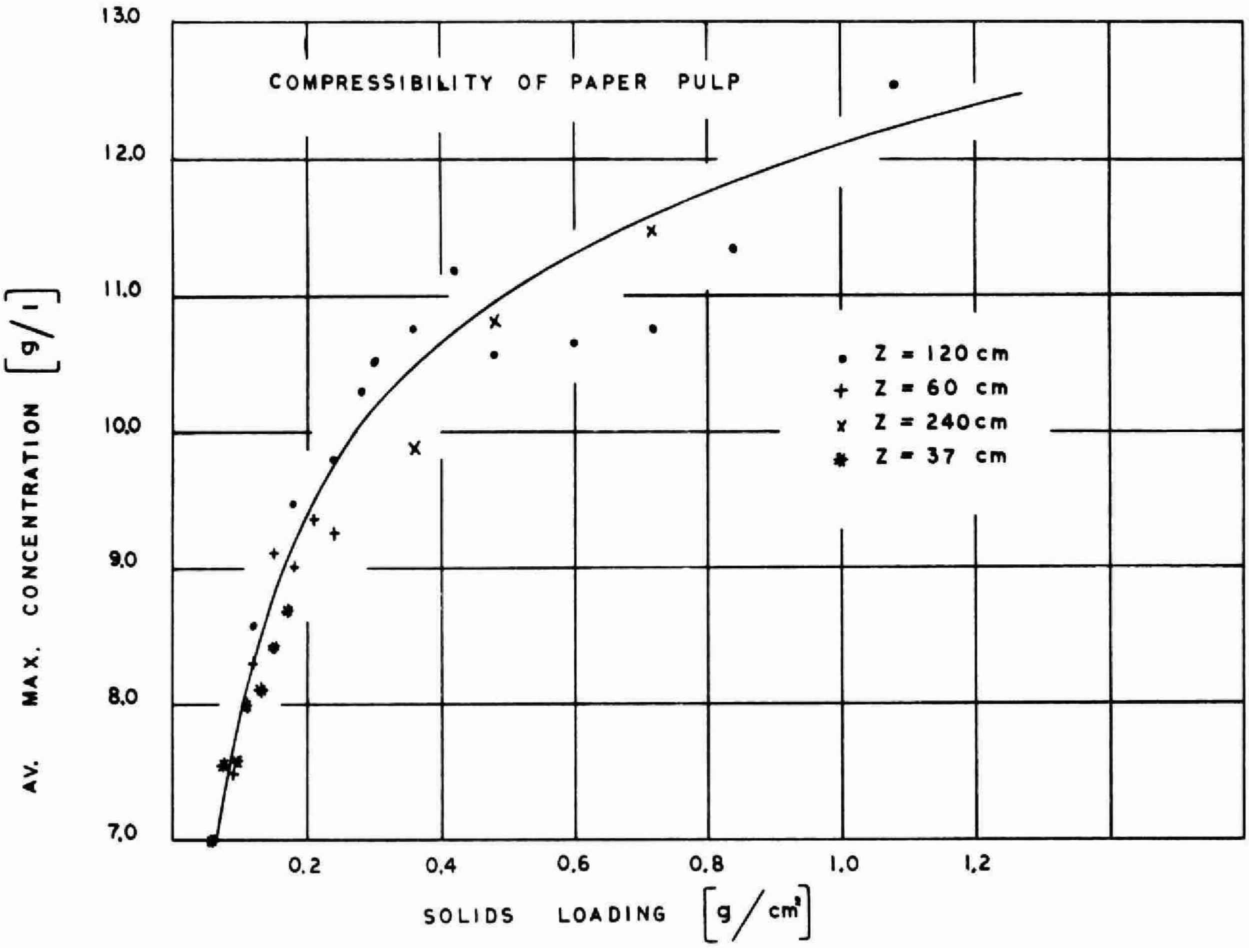
rate is only a function of local solids concentration and if both ordinate, interfacial heights (Z), and the abscissa time (t), of the settling curve are divided by the mass of solids per unit area ($C_i Z_i$) the settling curves should coincide. Figure 8 indicates that the experimental slurry is compressible and that the weight of solids influences the settling curves in the compression zone. The compressibility represents a departure from the ideal slurry invisioned by Kynch. The compression of the slurry, causing an increase in solids concentration, can only be attributed to the expulsion of water. This expelled water could dilute the slurry above the fixed bed. This would cause an error in calculating concentrations existing at the interface during batch settling. It is possible that the variation in settling rates for different weights of solids per unit area reported in the literature could result from the compression of the slurry. The variation in the average concentration in the mechanically supported bed of solids obtained at different solids loadings is presented in Figure 9.

The initial settling rates for various solids concentrations are presented in Figure 10. The settling velocity (u_i) of the solids is multiplied by the solids concentration (c_i) to give the solids flux. The batch flux plot essentially portrays the mass of solids per unit area that will settle through a plane within the slurry of a specified concentration. As previously mentioned with continuous thickeners the total solids flux consists of the movement of the solids within the slurry in addition to the movement of the slurry itself.

$$S = C(u + v).$$

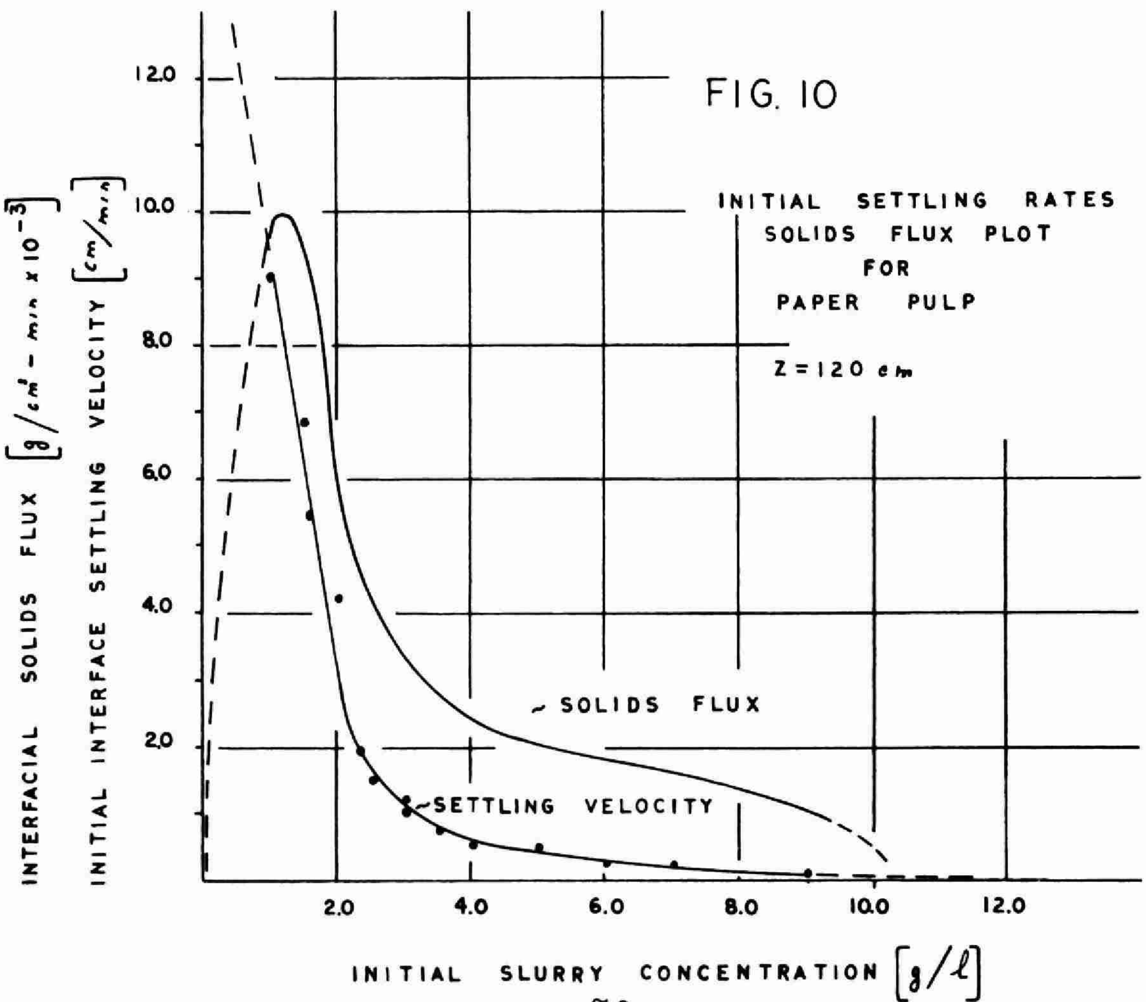
The batch flux plot gives the solids flux for a stationary slurry ($v = 0$) and this flux plot must be modified if it is to be useful in continuous thickening. If we arbitrarily select an underflow concentration C_u then the tangent on the flux plot from the point on abscissa corresponding to C_u will define the limiting flux for the slurry S_{LB} and the slurry concentrations which limits C_L. This limit will occur when the feed slurry has a value equal or greater than C_f ($C_i \geq C_f$). If it is assumed that all solids entering the thickener will leave in the underflow then the volumetric

FIG. 9



COMPRESSIBILITY OF PAPER PULP
Z = 120 cm
Z = 60 cm
Z = 240 cm
Z = 37 cm
AV. MAX. CONCENTRATION [g/l]
SOLIDS LOADING [g/cm²]
13.0
12.0
11.0
10.0
9.0
8.0
7.0
0.2
0.4
0.6
0.8
1.0
1.2

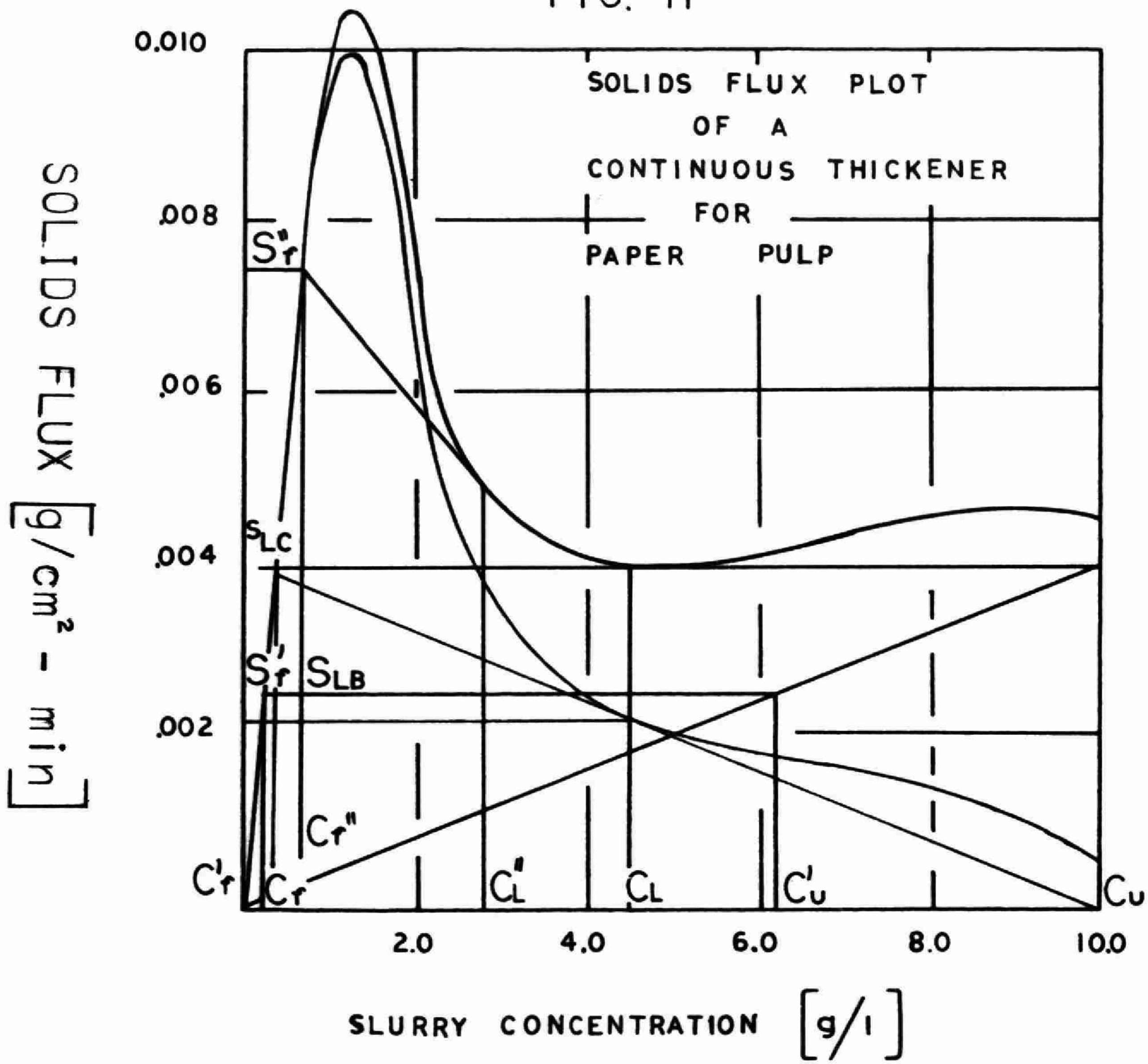
FIG. 10



INITIAL SETTLING RATES
SOLIDS FLUX PLOT
FOR
PAPER PULP
Z = 120 cm
SOLIDS FLUX
SETTLING VELOCITY
INTERFACIAL SOLIDS FLUX [g/cm² - min x 10⁻³]
INITIAL INTERFACE SETTLING VELOCITY [cm/min]
INITIAL SLURRY CONCENTRATION [g/l]
12.0
10.0
8.0
6.0
4.0
2.0
2.0
4.0
6.0
8.0
10.0
12.0

rate of underflow (Q_u) will be fixed when the concentration of feed C_f and underflow C_u are specified. The movement of the slurry may be expressed as:

FIG. 11


SOLIDS FLUX PLOT
OF A
CONTINUOUS THICKENER
FOR
PAPER PULP
SOLIDS FLUX [g/cm² - min]
SLURRY CONCENTRATION [g/l]
0.010
.008
.006
.004
.002
2.0
4.0
6.0
8.0
10.0
S''f
SLC
S'f
SLB
C'f
Cf
Cf''
C''L
CL
C'U
CU

This study has received financial support from the Grants-in-Aid of Research, Department of University Affairs, Province of Ontario, and was carried out in the Department of Civil Engineering, McMaster University. The assistance of J. Van Nynatten, Departmental Technician, in obtaining the experimental data is gratefully acknowledged.

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BANQUET NIGHT

SESSION CHAIRMAN
A. J. HARRIS
DIRECTOR, DIVISION OF RESEARCH
ONTARIO WATER RESOURCES COMMISSION

"MILL TAILING DISPOSAL AT THE HOLLINGER MINE, TIMMINS, ONTARIO"

BY

I. M. GORDON
MILL SUPERINTENDENT
HOLLINGER CONSOLIDATED GOLD MINES LIMITED

The Hollinger tailing disposal plant is situated about one and a quarter miles south of the mill. The area available for tailing covers 640 acres and is roughly one and a quarter miles long and three quarter miles wide.

Tailing was first deposited on the northeast section of the present site. This section, one mile long by a half mile wide, sloped from northeast to southwest, the slope amounting to 106 feet between the northeast corner and the low land to the southwest. The low land was wet and a considerable area was covered with muskeg up to 17 feet deep. It was drained by a brook running across the property in a southwesterly direction. Later when more ground was needed, the low lying mining claims adjacent to the south and west boundaries were acquired to allow for extension of the plant. This entailed some extra difficulties and expense that would not have been necessary had the whole of the present site been acquired with the original purchase.

At the present time the site contains 55 million tons of tailing. The top of the deposit is from 70 to 90 feet above the original low lying ground along the northwest, west, and south boundaries.

COMMENTS ON THE LOCATION OF THE SITE

The location of the site in relation to the mill was a good one, as it was on lower ground and gravity feed of the pulp to the distributing pumping station could be used for some years. Later, as the deposit of the tailing became higher, it was necessary to install a duplicate pumping station on top of the dam in order to distribute the tailing a distance of 21,000 feet around the perimeter of the site and 3,100 feet along centre dam.

The north and east dams stand on firm ground and are built 100 feet inside the boundary. The west and south dams stand 200 feet inside the boundary, where they stand on the lowest and poorest drained land. At the southwest corner of the site, the west dam was swung round to the southeast and the south dam was swung around to the northwest, to give a considerable length of dam facing southwest. This was done to avoid encroachment on an adjoining claim. This space, between the dam and the boundary, has been found adequate to contain all the material broken away from the deposits through slides or settlements.

GENERAL METHOD OF TAILING DISPOSAL

Tailing pulp is pumped from the mill to the tailing disposal plant. It is then pumped again to the upper pumping station which is at a 50 foot higher elevation and is used to deliver the pulp along the perimeter of the site and spilled through spigots in the pipe line. The solids settle out and the coarse sand deposited near the tank is used as spoil when a dam is raised later with a mechanical shovel. The water from the pulp flows to the tailing pond. From this pond it overflows to a re-settling pond which, in turn, overflows into a ditch draining the area.

METHOD USED TO COMMENCE THE TAILING DEPOSIT

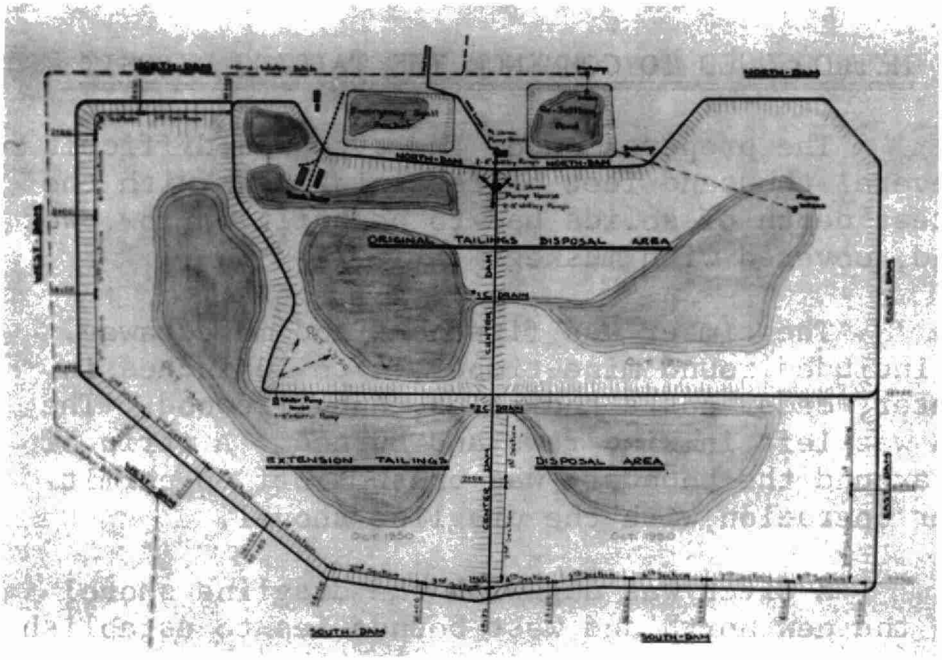
The preparation of the site was difficult as several thousand feet of retaining bank with the greatest depth of solids had to be built on low, wet ground, covered with muskeg.

The timber was first cut and moved away. This included round mine timber, 4 to 10 inches in diameter, cedar posts and poles, and firewood. The slash was left in wind rows and burned. A strip of land around the boundary was brushed off to permit easier operation with the dragline shovel.

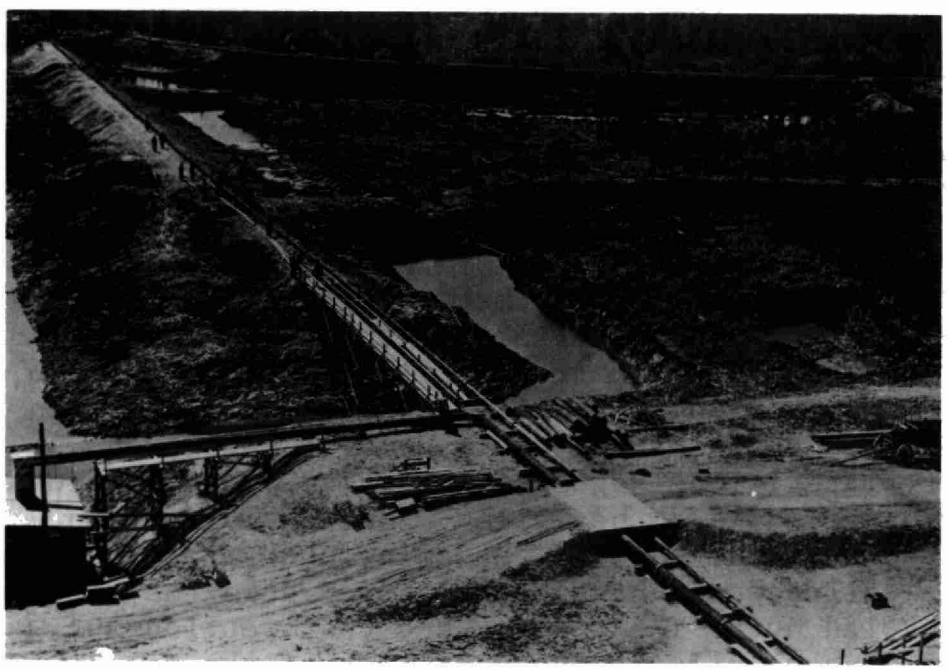
A ditch was dug with the dragline shovel along the new north and west boundaries to establish a new course for the brook draining the area. It was dug eight feet wide at the bottom and averaged three and a half feet deep, with banks sloped 2 to 1. It was 5250 feet long, with a sand and gravel bottom, except the last 1163 feet which were in muskeg. The grade of the bottom varied between 3.0 and 6.7 inches per 100 feet. When the water was turned on, its velocity scoured the bottom and eroded the banks in some places and deposited sand bars in others. It was necessary to smooth out the bottom and banks to ensure control over the course of the stream.

The dam was built by the dragline shovel, standing on movable timber mat sections when operating on wet ground. The material for the dam was taken from the area in which the spilling would take place, leaving a ditch on the inside. The ditch was broken up into pools by leaving cross dams of untouched country material at regular intervals. The cross dams allowed the pools to be filled, section by section, with the coarsest sand in the pulp, otherwise the finest of the solids would have been carried down the ditch and settled out. The coarse sand that settled out was required when building the next lift of the dam.

When the dam was completed, a wood stave pipe was laid on it. This pipe had tapered holes on the inner or ditch side, which were stoppered by wooden plugs until required. At each cross dam a trestle work,



Plan of Hollinger tailing disposal site.



Preparation of extension to original tailing disposal site, showing terrain, first dam of muskeg material, and drainage ditches leading to the original water pump at the southwest corner of the old deposit.

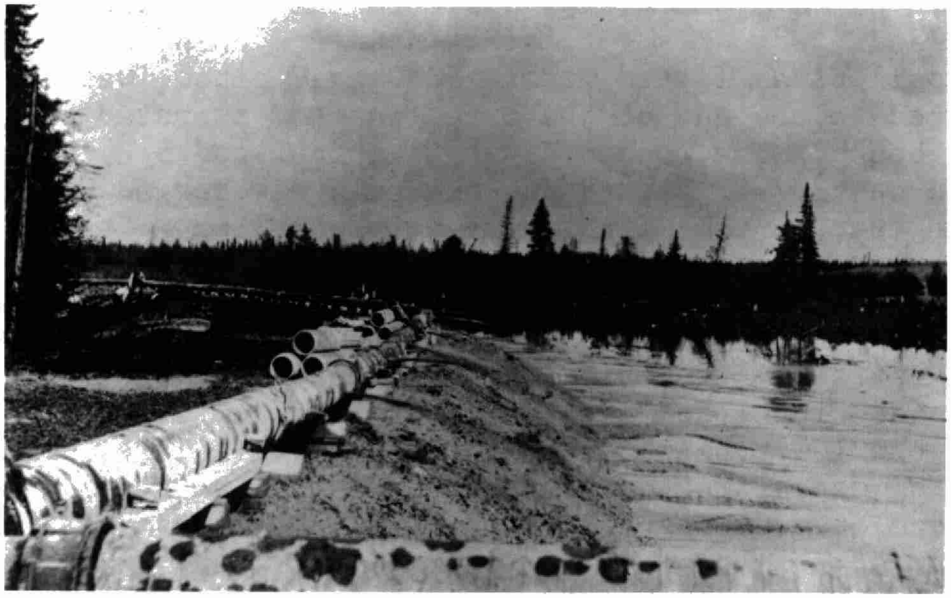
referred to as a bench, was built on the inner slope of the dam. When ready to start spilling pulp, a wood spill pipe, fitted with a 90 degree elbow, was connected to the end of the pipe line and elevated on the bench. The wooden plugs were replaced by chilled cast iron spigots and the pulp discharged through them to the ditch. The surplus slime in the pipe poured out of the elevated spill pipe on the cross dam. Excess water with fines overflowed the inner bank of the ditch. By using this method, much of the coarse sand settled in the ditch along the inner side of the dam and the finer sand and slime ran to the lower part of the spilling area. This method of depositing coarse sand near the dam had been developed during the early days of tailing site development.

Though building the dam began early in June, a considerable amount of frozen material was encountered which hindered the operation a little. Several parts of the dam built of frozen material slid down and flattened out after melting, and had to be rebuilt. At the lowest place on the site, where it was necessary to build the highest dam possible, the material was shovelled twice. The outer banks of the dam were built first, then a side of material, sufficient to complete the dam for a height and width, was shovelled in a pile and left to dry out for ten days. This part of the dam was 9 feet high and 20 feet wide.

A sump was dug at the southwest corner of the old deposit and a pump house installed from which an 8 inch Morris Pump elevated excess water to the tailing pond on the old deposit.

The centre dam of the old deposit was continued at a lower elevation due south to join the new south dam. A 50 foot wide opening, bridged by a trestle, was left half-way along this cross dam to allow water to flow to the pump sump from the southeast section of the spilling area.

After the operation was completed, the new area prepared for spilling was enclosed on all sides, and contained three separate areas suitable for spilling.



Preparation of extension to original tailing disposal site. First spilling operation from a dam built out of muskeg.

Preparation of extension to original tailing disposal site, showing terrain and the original water pumping station near the southwest corner of the old deposit. View looking north.

The lineal footage of dam built totalled 13,608 feet, containing 108,725 cubic yards of material.

SETTLEMENTS OF THE OUTER BANK

OF THE TAILING DEPOSIT

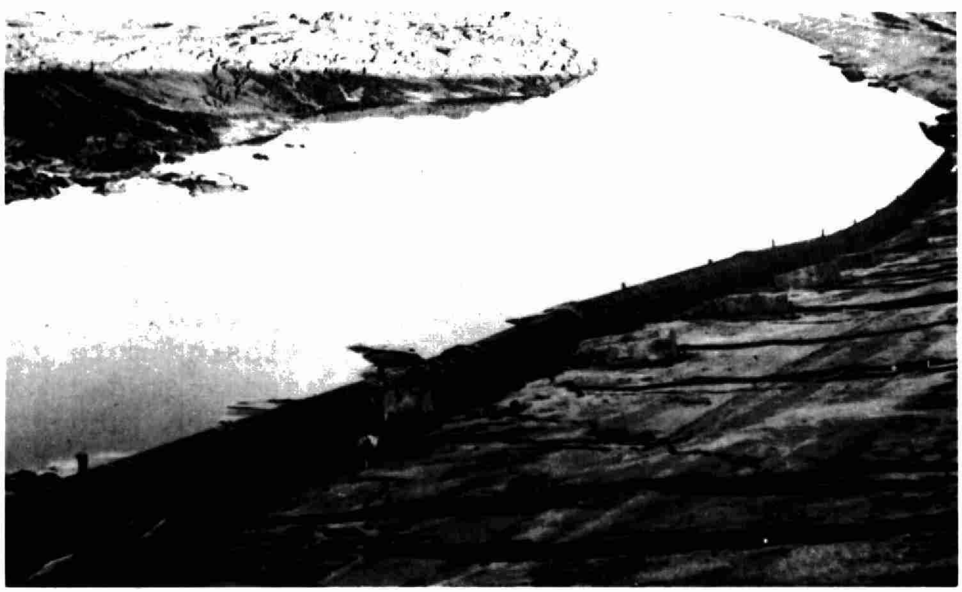
A major difficulty encountered at the tailing disposal plant has been the settlement and movement of the bank of the deposit while standing on wet, unstable ground. The settlements continue until a final equilibrium is established between the weight of the bank and the stability of the ground on which it stands. There have been no settlements since 1944.

Settlements have occurred on both the original site and on the extension to it. They have taken place only along the west and south banks where the dam stands on wet covered ground with 5 to 17 feet of muskeg resting on fine wet sand, or, on clay. The most frequent settlements have occurred where the bank stands on clay silt deposited on its flood plain by the brook whose course was changed to the outside of the deposit. Because the west and south dams were laid over wet ground on two occassions on the original site and on the extension to it, the extra work and cost of repairs arising out of the settlement have been doubled.

Settlements of the bank, resting on unstable ground, commence to occur when the dam has reached a height between 13 and 16 feet above the original ground level. The settlement comes unexpectedly and takes place **within a few minutes**. The toe of the bank slides outwards and all of the bank and part of the deposit loses elevation, the inner part losing more height than the outer. The bank is tilted over and the muskeg and unconsolidated ground are pushed ahead of the slide and piled up. After the settlement, the original ground level outside the bank becomes higher.

The extent of the settlement usually depends on the height of the bank. The maximum depth of settlement has been 20 feet, and the maximum length 1975 feet. On one occasion the displacement extended 300 feet into the deposit.

General view of bank after a settlement. The out-side bank of the deposit has flattened out.



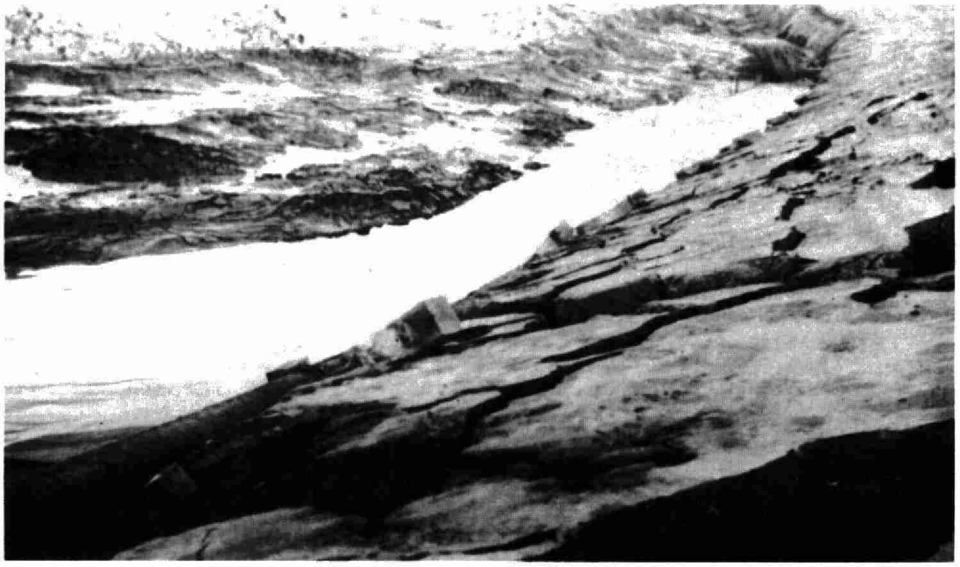
Close-up view of inner side of bank after a settlement.

After a settlement, sufficient time is allowed for the sand to drain before the dam is rebuilt with the dragline shovel. This is the preferred method as it is the least expensive and the results are satisfactory. During an emergency when the dam has to be built as soon as possible, without regard to cost or effectiveness, other methods have been used, such as building a plank wall lined with weather proof material on which the spigot line is laid on top in such a way as to allow the pulp to splash just inside the wall. The dam is also rebuilt by hand shovelling when speedy action is required and other methods cannot be used.

The tabulated description of the 17 settlements which have taken place on the extension to the original site gives an outline of the extent of these occurrences. The footages given along the west dam commence from the northwest corner and those along the south dam from the southeast corner.

DESCRIPTION OF SETTLEMENTS ON TAILING DEPOSIT EXTENSION

No.	Year	Month	Location Footages From:	To:	Length of Dam Affected Ft.	Approx. Height of Dam Ft.	Depth of Subsidence Aver. Ft.	Max. Ft.
1	1937	Aug.	3600W	3750W	150	15	6	8
2		Sept.	3300W	3800W	500	14	6	8
3		Oct.	4300S	4600S	300	15	4	6
4		Oct.	3800W	3950W	150	16	4	6
5		Nov.	3050W	3950W	900	14	6	8
6	1938	Jan.	3050W	3650W	600	14	4	8
7		Aug.	3050W	4300S	1636	21	6	9
8		Sept.	2650W	3300W	650	18	8	12
9		Oct.	2000W	2600W	600	16	8	12
10		Nov.	350W	1500W	1200	13	7	13
11	1939	Aug.	700W	1900W	1200	16	10	15
12		Sept.	2700W	4300S	1975	27	18	25
13	1940	Nov.	300W	1400W	1100	19	10	15
14		Dec.	2000W	3600W	1600	31	15	19
15	1941	Nov.	400W	2100W	1700	23	18	22
16	1943	Sept.	4200S	4600S	400	50	20	25
17	1944	Aug.	4350S	4500S	150	50	20	20



Close-up view of inner side of bank after a settlement.

Wrecked trestle and pipe-line after a settlement.

OPERATION OF PIPE LINES AND SPILLING PULP

There are two 12 inch diameter wood stave pipe lines available through which tailing is pumped from the mill to the disposal plant. They are supported partly on a trestle and partly on a prepared bank of sand. One pipe is spare. Each line is 7,820 feet long and has an average grade of 0.85 per cent downwards from the mill.

The density of the pulp carried usually varies between 40 and 50 per cent solids (Sp.Gr.1.35 to 1.47) depending on the milling rate. When the milling rate is low, the pulp density is low because a minimum quantity of water must be used to wash the belt conveyor carrying cake discharged from the oliver filters. This wash water is used when repulping the cake before it is pumped into the pipe line. The pressure in the pipe line is 17 lbs. per sq. inch in the winter and 8 lbs. in the summer, taken at a point 102 feet south of the original intake. The difference in pressure is ascribed partly to the greater viscosity of the colder pulp and mostly to the presence of air in the pipe line, which can not escape at the joints because of a coating of ice.

When the milling rate is 4,500 tons daily, and the pulp density is 45 per cent solids, the pipe carries 1,190 U.S. gallons per minute. The average velocity of the pulp is 3.4 feet per second in 10 inch pipe. The friction head loss ranges between 0.95 and 1.20 feet of pulp per 100 feet of 12 inch pipe line, depending on the season.

An appreciable quantity of heat is retained in the pulp in winter during its passage between the mill and the spigot discharges. At a time when the air temperature was minus 4.0 degrees Fahrenheit and the rate of flow of pulp was 1,255 U.S. gallons per minute with a pulp density of 49.5 per cent solids, and a temperature of 43.7 degrees Fahrenheit, at the mill, there was a drop of 3.6 degrees Fahrenheit when the pulp reached the No. 1 booster pumping station, 7,820 feet away, with a further drop of 3.6 degrees Fahrenheit, when the pulp was discharged from the most

distant spigot, 14,000 feet from the mill. The pulp does not freeze as long as it is kept moving along the pipe line. The insulation afforded even by wet wood is not usually appreciated.

PIPE LINE DRAINAGE, 12 INCH PIPE

When the flow of pulp from the mill is stopped, the pipe line is washed out with as much water as it will carry for 2½ hours. A quick opening valve is then opened to discharge the water into the emergency spill pocket, and the water is continued for another ½ hour. The water is then shut off and the pipe line drained into the spill pocket. The operator then checks the condition of the pipe line to make certain that the sand has been washed out.

EMERGENCY SPILL POCKET

An emergency spill pocket receives drainage from the pipe line carrying pulp from the mill. It is five acres in area and is located on the north side of No. 1 booster pump station. It is surrounded by a low bank to ensure a depth of eight feet of water in the pool. Excess water overflows into an intake box, and is piped through the north bank to discharge into the drainage ditch.

BOOSTER PUMP STATIONS

Two permanent pump stations are used to distribute the tailing pulp. No. 1 booster pump station, the lower one, is situated between the emergency spill pocket and the resettling pond, 500 feet inside from the north boundary. No. 2 booster pump station, the upper one installed in 1949, is built on top of the tailing deposit nearby, at a 50 foot higher elevation. It is located 90 feet south from the north end of the old part of the centre dam.

The two booster pump stations are similar. There are two 8 inch Wilfley pumps installed at each station, one of which is a spare. The pump suction box is connected by a vertical riser to the bottom of the feed box. The intake is opened and closed by

a rubber covered truncated cone valve which can be raised and lowered by a hand wheel.

SPILLING PULP

There are 13,000 feet of 10 inch diameter wood stave pipe used to distribute the tailing pulp from No. 2 booster pump station to the various parts of the tailing disposal area. The pulp is usually discharged directly through spigot openings in the pipe line but, when a high wind blows the streams of pulp against the bank, short length of hose are used to carry the pulp away from the spigot openings. Tapered bung holes, 1¼ inch in diameter, are bored in the wood pipe at 6 foot to 8 foot intervals, using a No. 2 size barrel bung hole borer, with a taper 1-1/8 inch to 2 inches. Tapered cast iron spigots, chilled at both ends and in the interior to take the wear, are then driven into the openings. The discharge opening of the spigot is 7/8 inch. White pine tapered plugs are used to close the spigot openings.

The spill is made through spigots over a distance of 600 feet at a time. The end of the 10 inch pipe line is elevated to an angle of 45 degrees from the horizontal and directed to the inside of the bank. Excess pulp spills out of the end of the pipe and a head of pulp is maintained at the spigots. Alternate spigots are opened and run for about two hours. Then, starting at the end of the pipe line, the spigots are closed and intervening ones are opened. The actual manipulation depends on the way the sand builds up, the object being to raise the fill evenly and to avoid the formation of erosion channels. It is essential that the coarse sand in the tailing pulp should be deposited against the inner face of the bank to permit use as spoil when raising the height of the bank at a later period. Spilling through spigots is discontinued when the sand has been built up to the level of the bottom of the pipe.

The discharge of tailing pulp through spigots, or spigotting, is done preferably during the summer months. If spigotting is done in winter a considerable part of the water is frozen before it can reach the pond;

Close-up view of spilling pulp in a ditch. Note overflow of pulp from end of elevated pipe. Spigots have been replaced by short lengths of hose, used when filling the ditch or when spilling pulp into the wind.

consequently, at this season the pulp preferably is spilled into a pond where solids settle out in water under ice, and the excess water is discharge without freezing.

When spigotting is done correctly, the coarse sand settles out close to the bank, fine sand settles next, followed by the slimes. Finally, clear water collects in the tailing pond at the greatest distance from the spilling place. Care is taken to maintain the water level in the pond about 15 feet below the top of the bank to ensure adequate drainage. The solids in the tailing deposit settle out at a slope of 1.6 feet in 100 feet.

10 INCH PIPE LINE DRAINAGE

The 10 inch pipe line carrying the tailing pulp to the section where it is spilled must be drained after each shut-down. Irregularities in the grade of the pipe line are made use of and drain tees are placed at low spots and opened to obtain rapid drainage. This prevents much of the sand from settling out.

DISCONNECTING 10 INCH PIPE LINE

When a 10 inch pipe line is disconnected there is usually several inches of sand in the pipes, unless precautions are taken. All spigots are closed off for one day previous to disconnecting the pipe line, and the full flow of pulp is used to wash out some of the unsettled solids and loosen the remainder. Then a crew of men dressed in oilers, breaks the line quickly while half of the flow of pulp is running through it. After this has been done little or no sand remains in the pipe.

PRIMARY AND SECONDARY SETTLING PONDS

Advanced planning must be carried out to ensure that the level of water in the ponds during the winter months is sufficiently high to allow for the maximum thickness of ice likely to be formed on top of a sufficient depth of water. When the depth

of water is insufficient, the ice interferes with its flow to the outlet. The level of the primary spill area pond should be between 12 and 15 feet below the top of a newly made dam and the water edge not closer than 300 feet from the inside of the dam by the beginning of the cold weather.

The water elevation in the secondary settling pond is controlled by a vertical reinforced concrete hexagonal cross-section tower, 3½ feet across the flats inside. Ports, 13 inches square in area, are staggered at intervals, 1½ feet apart, up two sides of the hexagon, 120 degrees apart. Any port may be closed off tightly when required. A 14 inch diameter wood stave pipe is attached to one face of the tower 15 inches above the bottom. It is buried in a ditch dug 4 feet deep through ground that was originally dug, and covered with six feet of sand and tailing. The rock was blasted out of the ditch where necessary to ensure that a grade of 2.1 inches per 100 feet downwards to the resettling pond was maintained. Reinforcing rods extending from the top of the structure are left to take care of subsequent additions.

RESETTLING POND

The resettling pond was made on sandy ground using a bank of coarse, natural sand. It is about 5 acres in area and is located northeast of No. 1 booster pump station. It receives the overflow through the 14 inch wood stave pipe from the secondary settling pond. The overflow from this resettling pond runs into an intake box from which a 14 inch diameter wood stave pipe is led through the dam on the north side. The water discharges to the ditch that drains the area.

DISCARDED WATER

Water leaving the tailing disposal area carries only a trace of solids. It contains a non-lethal concentration of hydrocyanic acid along with a trace of cuprous cyanide. It also contains minor amounts of non-toxic alka-

The amount of cyanogen radical (CN) in the water averages 3.4 p.p.m. (2 Samples), as determined after using a distillation method. This amount of cyanogen is equivalent to 0.128 lbs. of sodium cyanide per ton liquid. In other words, 4 Imperial gallons of water contain the equivalent of 1.9 grains of sodium cyanide. The minimum lethal dose of hydrocyanic acid is said to be 4 milliliters of a 2 per cent aqueous solution, which is equivalent to 2.24 grains of sodium cyanide.

The effluent from the tailing area falls to a brook where it is diluted and the degradation of the toxic compounds containing cyanogen along with the non-toxic ferrocyanide and thiocyanate continues slowly under natural conditions. The water in the brook is harmless to fish and vegetation.

DAM BUILDING

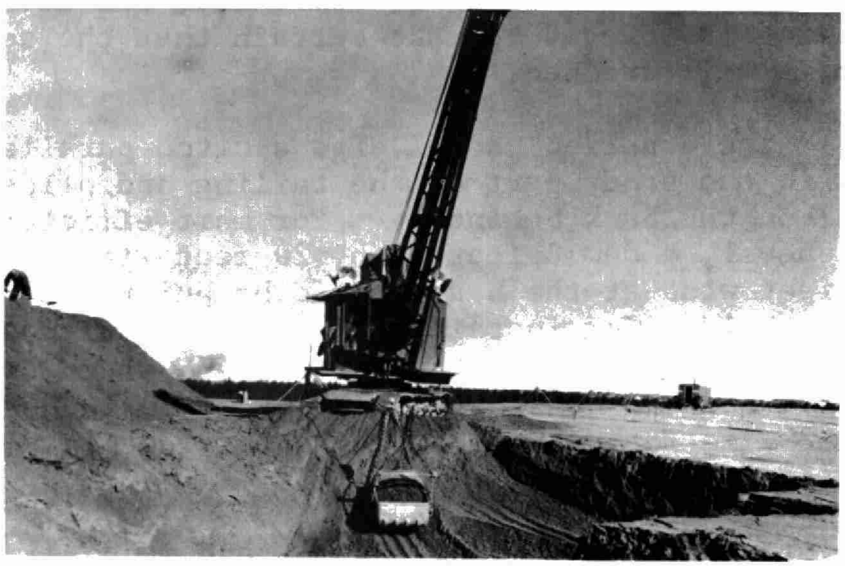
The rim of the bank must be raised from time to time, and a sufficient amount of work must be done on any section to average a 3 foot rise in level yearly. This applies to a spill area of 240 acres when the milling rate is 20,000 tons weekly.

Before shovelling is commenced, the level of the tailing is lowered to make certain that the sand near the rim is well drained.

The dragline shovel digs a ditch parallel with the rim in the sandy part of the tailing and piles the material on the bank behind it. For most efficient use of the shovel, a dam 8 feet high, 20 feet wide at the top, and 40 feet wide at the base should be built. This allows sufficient width for installing the distribution pipe line, and provides adequate roadway for the shovel to travel upon. The top of the dam is sloped 8 inches to 10 inches toward the inner edge for drainage. The outer face is sloped at 1½ to 1, and the inner face 1 to 1.

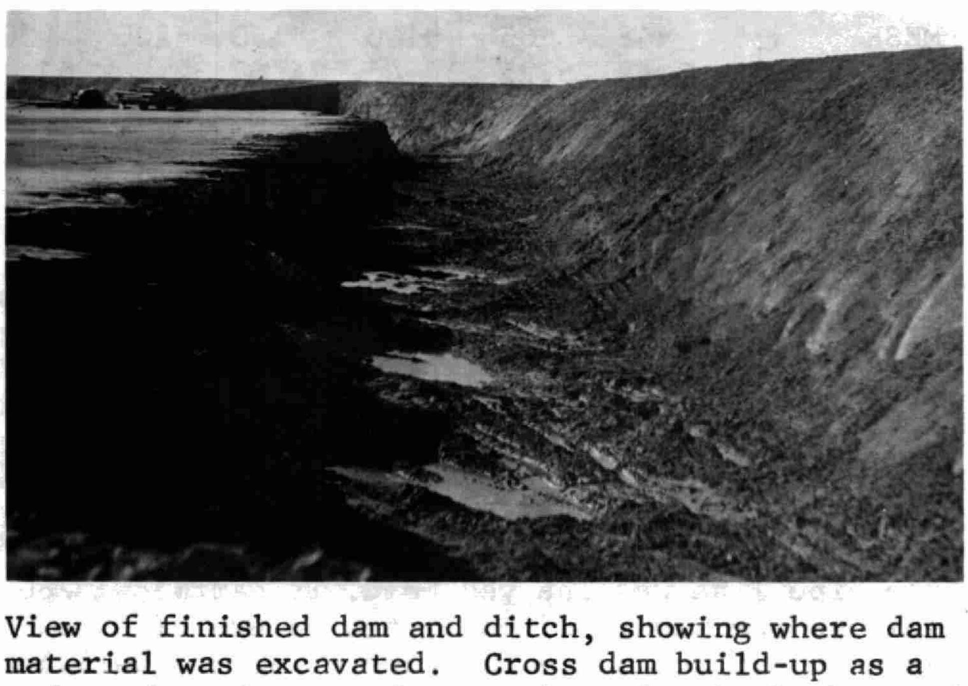
The ditch that supplies the sand is dug in 600 foot sections, separated by a transverse bench of solid fill, 8 feet wide at the top. The bench is built up to serve as a road from the deposit to the top of the dam and is

General view of a junction of the high and low level deposits. Eventually the lower deposit will be raised to the same height as the upper one.



Dragline shovel operation on a well drained deposit, building a dam.

Dragline shovel operation on a well drained deposit. Building a dam. This view shows a cross-section of the new dam, 8 feet high and 20 feet wide at top.



View of finished dam and ditch, showing where dam material was excavated. Cross dam build-up as a road, and a pipe stand, are shown in the background.

used when pipe and other material are replaced.

Under good shovelling conditions, the drag-line shovel can move 1.4 cubic yards of sand per minute and deposit it in place to make a dam. Generally, about 12,000 lineal feet of dam is built every three years to take care of our current tailing requirements. The work is usually completed in about 230 work shifts at a cost of $0.08 per cubic yard.

After the dam has been built, the 10 inch pipe line is reinstalled on 8 inch wood blocks along the inner edge of the dam. When spilling is again begun, the ditches are filled first, as rapidly as possible, into one 600 foot section at a time. Fairly good classification is secured, the coarse sand displacing the finer sand and slime, which flow out of the ditch and settle out on their way to the tailing pond. After the ditches have all been filled, regular spilling operations are resumed.

SIZE OF TAILINGS

For the past 20 years the average sizing of solids in the tailing, using Tyler standard seives, are given as cumulative per cent weights as follows:

MESH	+35	+48	+65	+100	+150	+200	-200
%	0.05	0.69	6.25	14.45	24.67	32.90	67.10

FLOW OF PULP THROUGH PIPE LINES

The velocity of the flow of pulp in a wood stave pipe line is governed by the settling rate of the most rapid settling portion of the pulp at the given dilution. The finer the solids, the less the velocity required. A velocity between 3.5 and 4.0 feet per second has been found satisfactory for carrying Hollinger tailing pulp between 33.3 to 50.0 per cent solids (Sp.Gr. 1.27 to 1.47), after the solids have been ground between 23 and 17.5 per cent on 100 mesh and between 63 and 70 per cent through 200 mesh. When the pipe line was one year old, it carried 1,280 U.S. gallons per minute of pulp at a Sp.Gr. of 1.46, or 49 per cent solids (5,500 tons of solids daily). The average velocity was 3.63 feet per second, and the

friction head required was 0.89 feet of pulp per 100 feet of pipe.

After ten years' operations, the pipe lines were taken apart to remove scale and obstructions. This job is now done annually along the 2,000 feet of pipe nearest to the mill, where most of the carbonates are precipitated out. At the same time, worn pipes are turned around through 180 degrees, or are replaced, and the grade of the pipe adjusted.

LABOUR AND SUPERVISION

The job of tailing disposal is an essential phase of milling operation and is given regular supervision by a foreman engaged exclusively on this work. One operator is employed on each shift to operate the plant. He patrols 6,000 feet of 10 inch pipe line, alternates the spill of pulp from the spigots, and inspects the booster pump stations. A maintenance crew of two men is employed on day shift. An additional crew of men is employed when the dam is being built and for other large jobs.

COST OF TAILING DISPOSAL

The cost of operating the plant, handling 1,000,000 tons per year, has been 2 1/2 to 2 3/4 cents per ton over the past several years. An additional cost of 1/2 cent per ton usually covers the cost of building the dam when required every third year. Included also is the cost of growing grass on the banks of the tailing deposit to retard erosion of the slopes by water and wind.

GRASS GROWN ON TAILING BANKS

The Hollinger tailing is 2.84 Sp.Gr., 35% Quartz, 22% Carbonates, 3.6% Pyrite, and the balance Silicates, Hydrous Silicates, and minor amounts of other minerals. Tailing oxidizes from a grey to a brown colour most rapidly in the sandy parts of a deposit which is subject to alternate periods of wetting and drying. There is no appreciable oxidation when the tailing is kept wet. An unsuccessful attempt was

made years ago to grow vegetation on oxidized tailing which had been exposed to the air for ten years. It was then realized that manufactured chemical fertilizers were not sufficient to establish a healthy and permanent growth of grass on oxidized tailing, and that humus, to support bacterial life, was also required.

In 1946 several experimental 1/100 acre grass plots with various fertilizers and seeds were started on the north bank of the old tailing deposit, which has a slope 1½ to 1. These tests disclosed that New Zealand Fesque stood up well after two winters, so we have continued sowing it since that time and now have a total of 28 acres of banks of slopes consisting of 18,000 linear feet at a flat grade of not more than 1½ to 1 and from 50 to 90 feet in length have been covered. The slope facing north is 5,800 feet long, the west 3,800 feet, the south 5,000 feet, and the east 3,400 feet.

The other grasses, Kentucky Blue, Timothy, Red Clover, of the original tests have all died out. The New Zealand Fesque does not develop to the seed stage, but forms a heavy spreading root system which stands up well, either in dry summers or severe winters. This heavy turf binds the tailing which prevents blowing and channelling of the slopes. The dams on the north and west which get the prevailing winds are from 80 to 100 feet above the surrounding ground.

We use Milorganite as fertilizer. Due to its granular form it does not blow away easily and forms a base of humus for the small seeds to start growth from. In addition, 20% Super Phosphate and 60% Muriate of Potash are used with Yellow Blossom Sweet Clover as a nurse crop. The most satisfactory rate of application for our conditions, with a Ph.8 tailing base, is as follows:

	Milorganite	20% Super Phosphate	60% Muriate of Potash	New Zealand Fesque
Rate/Acre	2000 Lbs.	800 Lbs.	400 Lbs.	75 Lbs.
Cost/Acre	$120.00	$35.00	$35.00	$55.00

Also Yellow Blossom Sweet Clover at 25 lbs. per acre, costing $5.00 per acre. Total cost per acre is $250.00

In developing a new slope for sowing, all channels are filled in, allowed to settle for a few days, then the entire area to be sown is fertilized and very lightly 'hand raked'. Care must be taken not to rake deeply as the surface will only wash down and channelling start again. About two weeks later when the area has settled and hardened on top, the seed is sown just before a light rain or drizzle and raked in very lightly. We have been fortunate in nearly always getting the seeding done under these weather conditions. However, if the weather is unsettled, we start at the top and sow in 10 foot widths. By this method you develop the top of the slope first which overcomes the chances of the whole length washing down to the bottom under extreme weather conditions. It should be noted that if the seeds are raked below 1/3" to 1/2" a large number will not germinate. On the other hand, if the seeds are not raked below the soil surface, at least one-third will not germinate and the remainder will be subject to the effects of wind and water erosion.

A top dressing of 400 lbs. of Milorganite per acre is applied in the autumn of the first season. Additional dressing has not been necessary, as a good thick turf has been established by the second year.

The mining industry has been faced with the problem of the disposal of tailing since its inception. A considerable amount of money, time, and effort is devoted to this section of the operation. As the mining industry has developed, the methods of spilling the slime and the construction of the dam has improved so that most slime dams give very little trouble.

Various ways of preventing erosion and future pollution of streams near the disposal area are now under study. The suggestion of the establishment of the growth of grass on the slopes and the planting of willow cuttings to form effective wind breaks on the top of the deposits are effective means of control. It is noted that many of the local older tailing deposits have now a considerable amount of scrub brush growing naturally on the slopes and near the ponds on top of the deposits. It is evident that this scrub growth is gradually covering larger areas.

BANQUET

HEAD TABLE

"RADIOLOGICAL CONTROL OF URANIUM MINE AND MILL WASTES"

BY

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CONSULTING ENGINEER
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RIO ALGOM MINES LIMITED

This talk is somewhat of a sequel to one presented at the Seventh Ontario Industrial Waste Conference, in 1960 by K. D. Hester[1], formerly Chief Chemical Engineer of Rio Algom Mines Limited. It described the Elliot Lake uranium area, its history, mill processes, water supply and problems in waste disposal. At that time the main problems were chemical rather than radiological. Concentrations of uranium and radium in drinking water were well below the levels permissible at that time and also lower than those recorded for the two years previous to 1960.

Within this paper, I propose to dwell mainly on the problems of radiological waste disposal that have developed in recent years and what has been done to solve them.

First, a brief review of the process will be provided as background information. Uranium ore excavated from the mines is crushed, pulverized in wet grinding mills and then leached with sulphuric acid to dissolve the uranium. The leaching solution is separated from the waste pulp by thickeners and drum filters. The pulp is discarded and the filtrate is partially neutralized so that uranium can be picked up in ion exchange columns. The uranium is stripped from resin with nitric acid and precipitated with lime and ammonia. The precipitate is thickened, filtered, dried and then packaged in steel drums for shipment. Part of the barren solution is recirculated; the remainder is neutralized either separately or partially along with the waste pulp. Both are combined into a slurry and pumped to a tailings disposal pond at a pH of 8.

The pulverized waste rock settles in the pond and carries down with it chemical wastes which were precipitated during neutralization. These chemical wastes are iron, calcium, aluminum, thorium and radium in the form of hydroxides, sulphates and nitrates. The neutral overflow from the pond, consisting of water plus a few dissolved salts, finds its way to one of the streams or lakes in the watershed of the Serpent River.

WATER AND REAGENTS

The water and reagents used in the process for each ton of ore treated are approximately as follows:

Mine Water	1.35 tons
Fresh Water	1 ton
Sulphuric Acid	72 lbs.
Calcium Oxide	42 lbs.
Nitric Acid	2.7 lbs.
Ammonia	0.37 lbs.
Glue	0.1 lbs.
Floculent	0.03 lbs.
Barium Chloride	0.11 lbs.

Most of the water pumped from the mine is drawn from surface water to control dust during drilling, blasting and ore handling operations. A small amount of water is used for drinking, while the remainder emanates from the mine workings through crevices, faults

and diamond drill holes. The water that issues naturally from the rock contains some dissolved uranium, iron and radium. An additional quantity of these materials is picked up by the water as it is used for drilling, for spraying walls and broken rock and as it seeps through the latter. The dissolving action is augmented by an unknown extent by acidity due to oxidation of sulphides which in turn is expedited by bacterial action. The water reaching the pumping stations has a pH ranging from 2 to 3. The resulting corrosion of the equipment is a costly problem.

During the past year partial neutralization was initiated underground by adding a slurry of caustic into the collecting dams; this protects the pumps and pipes. All of the mine water is pumped to the mill to be used in the process and to recover the uranium content.

DISPOSAL OF MILL WASTES

Before the Ontario uranium mines were brought into production, the following conditions for waste disposal were agreed upon between mine officials and the provincial departments of Mines, of Lands and Forests and of Health:

1. Neutralization of acidic waste liquids with lime and/or ammonia.
2. Use of certain swamps, pot holes or small lakes for waste storage.
3. Construction of dams and decant towers to contain the solids and clarify the overflow.

These conditions were fulfilled by the mines except for certain accidental failures of dams, decant wells and pipelines which permitted some very fine solids of waste to overflow into streams.

The most substantial dams are constructed with a base of crushed waste rock obtained from development work underground. The inside is lined with mill wastes that have settled in the pond. The coarser portion,

called sand, is preferred for this purpose particularly next to the crushed rock. The coarse sand is also used to build up the height of the dam as increased capacity is required. The fine material, called slime, settles in the centre.

DEVELOPMENT OF RADIOLOGICAL PROBLEMS

A number of factors contributed to the concern that developed regarding the quality of drinking water in the two uranium mining areas. This apprehension culminated in the appointment, in November 1964 by the Prime Minister of Ontario, of a Committee of Deputy Ministers:

> "to asses fully the problems of radiological pollution of waters adjacent to the Elliot Lake and Bancroft mining areas in Ontario".

Radium, which is the contaminant under consideration, is about the most insoluble substance known. Only two parts of radium sulphate will dissolve in 100 million parts of water (0.02 mgm/l). However, this quantity is still above the permissible concentration for drinking water, which years ago was set at 10 parts in a million-million parts (10 pCi/l). Radium occurs naturally, in uranium ore, in a very finely divided state. When the ore, which is broken into fine particles by blasting, crushing and by grinding mills is intimately mixed with acidic water for many days underground and much more vigorously and intimately for several days in the mill, a small amount of it dissolves.

Dr. Shearer, in his comprehensive paper on this subject which was presented at the Eleventh Ontario Industrial Waste Conference, in 1964, indicated that in acid leaching mills on the Colorado Plateau about 1/2 of one percent dissolved. According to our calculations 1/4 of one percent of the total radium dissolves in the mine and mill process water. The other 99.75 percent remains locked up within the waste rock, which becomes compacted in the tailings ponds. It is our experience that seepages from these compacted old tailings ponds sometimes yield high readings in some chemicals, but low in radium, indicating that the latter does not migrate directly through dikes made of tailings nor vertically

by hydrostatic pressure. It bears emphasis that radium does not dissolve unless the fine particles are in vigorous contact with copious quantities of water. The ideal proportion is 1000 parts of water to 1 part of fines containing radium. This condition can be met only in a milling process or when a substantial stream flows over tailings. Not even a very heavy rainstorm on a pile of compacted tailings will effect the dissolving of radium.

Some of the dissolved radium, mentioned earlier, precipitates upon neutralization of the tailings slurry and settles in the pond. A portion, for about eight years, found its way into some public waters, but was diluted sufficiently so that it did not become a radiological hazard.

However, growing concern did develop about two or three years ago due to a combination of circumstances. Firstly, in spite of the fact that most uranium mines had closed by the end of 1961, concentrations of radium in several lakes kept climbing slowly within the acceptable range. Secondly, the problem was not a familiar one and there were uncertainties among government officials about the ability of the mines to stop the increase. It was suspected that the main reason for the increase was due to the leaching of fine particles that had been carried downstream with the overflow from tailings and during certain spillages. It is now obvious that the main contribution was from radium dissolved in the mine and mill waters and that this can be successfully controlled. Thirdly, due to an increasing number of sources of radiological exposure in present day living, some radiation scientists introduced greater safety factors into the interpretation of the Recommendations of the International Commission on Radiological Protection. For example, the MPC of 10 pCI/litre of Ra-226 in drinking water for fringe populations ("persons living in the neighbourhood of controlled areas")[2,3], which had been in effect since the beginning of mining operations in Ontario, was questioned and there was a move to apply an MPC of 3.3 which had been assigned to general populations. This change was accepted too literally and prompted an expression of urgency on the part of some government officials which eventually received exaggerated and political prominence in the press. Fourthly, the growing consciousness throughout not only Ontario, but also

Canada and the United States, towards the need for conservation of water has resulted in a general reaction against industrial and domestic contamination of lakes and streams. These four factors prompted the appointment of the Deputy Ministers' Committee.

COMMITTEE REPORT

Following a year of investigation the Deputy Ministers' Committee reached a number of conclusions[3] (quoted in part):

> "After a detailed review of field survey data and consultation with personnel of the provincial public service, Federal Government regulatory agencies, the mining industry, and technical specialists in the field of radio-chemistry, the committee has concluded that:
>
> 1. Low level radiological contamination has occurred in certain public waters in the Elliot Lake and Bancroft mining areas as a result of waste disposal practices which have been considered to be standard in the mining industry.
>
> 2. Radiological analyses of samples of surface waters taken in both mining areas indicate that there is no danger to persons drinking the waters in question, since the concentrations of radioactivity are within acceptable limits for short-term exposure promulgated by international bodies. However, improved waste control measures are needed to reduce the levels of radioactivity for prolonged exposure."

The Committee also made a number of recommendations (quoted in part):

> "2.. In establishing regulations for the control of radioactivity in public waters arising from uranium mining and milling operations, the objectives of the Ontario Department of

Health should initially be adopted by the Province. These objectives are as follows:

(a) In accordance with modern scientific knowledge and opinion, any unnecessary exposure to radioactivity should be kept to a minimum.

(b) Concentrations of from 10 to 3 picocuries of radium-226 per litre of water should be adopted as the initial objectives to be attained in public drinking waters in the Elliot Lake and Bancroft areas.

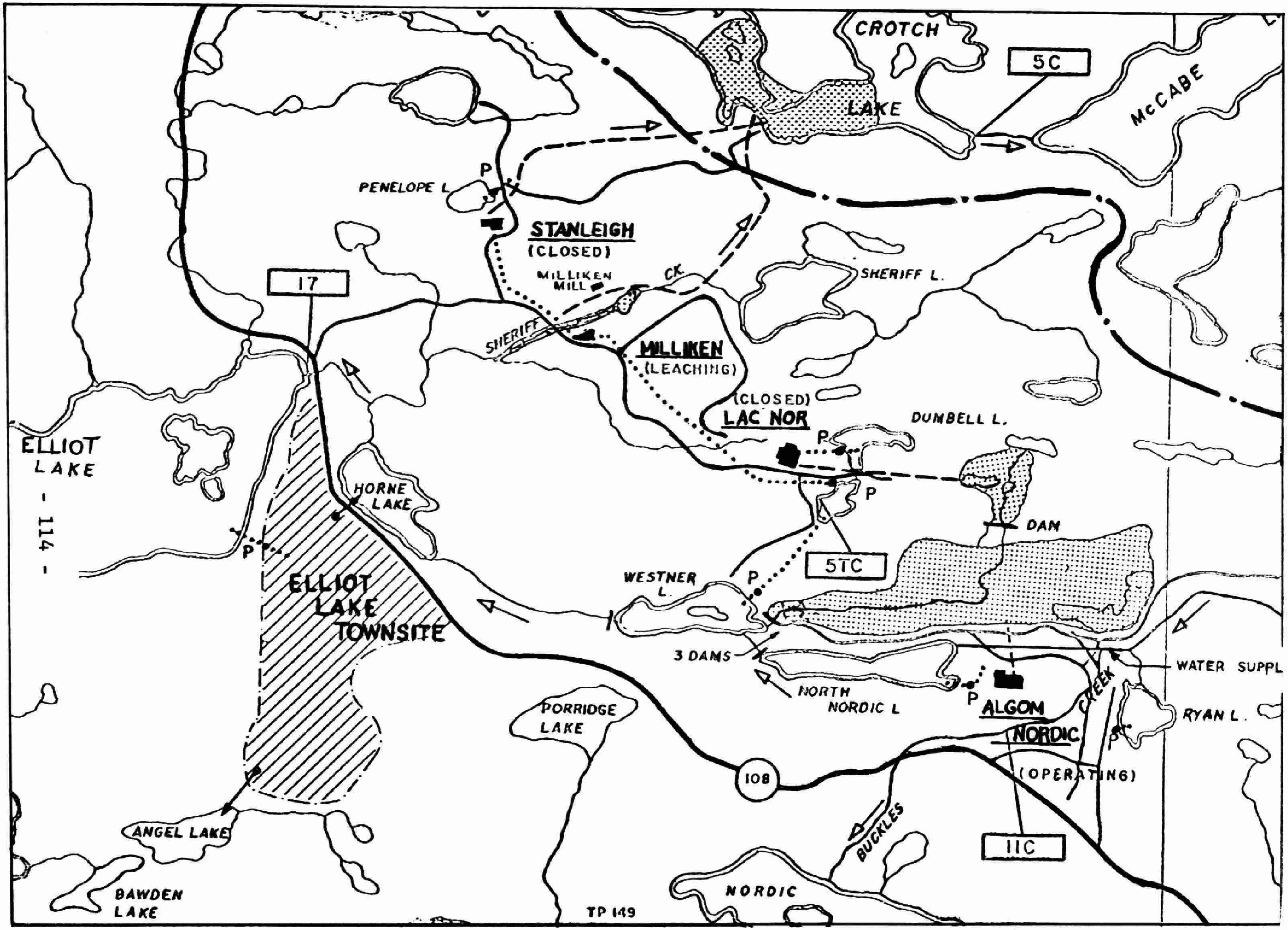
(c) Concentrations of from 30 to 10 picocuries of radium-226 per litre of water should be adopted as the initial or first level objectives to be attained in those lakes and streams where present levels are in excess of this range."

MAXIMUM PERMISSIBLE CONCENTRATIONS

Those particularly interested in this aspect are referred to the Committee's Report for a full discussion of the interpretation of the recommendations set down by the International Commission on Radiological Protection for the MPC for radium in water. This was written following a very intensive study of the subject made by the Ontario Department of Health. The study involved consultations with various radiation experts in Provincial and Federal Government departments, including the Canadian member of the ICRP's Committee II, on Permissible Dose for Internal Radiation, who stated that there is no need for concern about radium in drinking water until concentrations exceed 20 pCi.

CONTROL MEASURES

In view of the apprehensions, even though unwarranted, particularly of some residents in the only active uranium area within the Province, the mining companies involved expedited control measures which have already, in most instances, reduced radium contamination to levels which conform with the Committee's objectives.

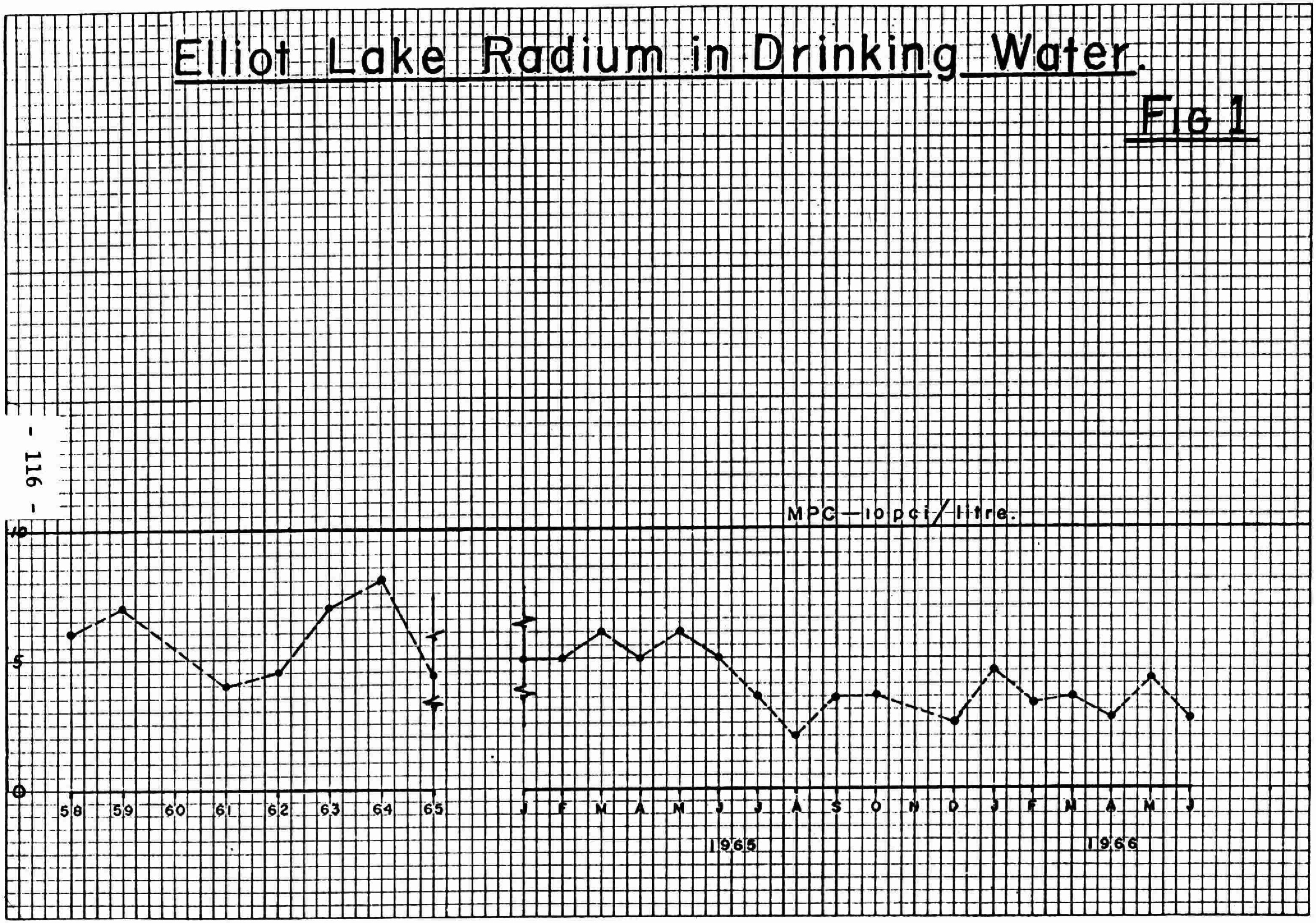


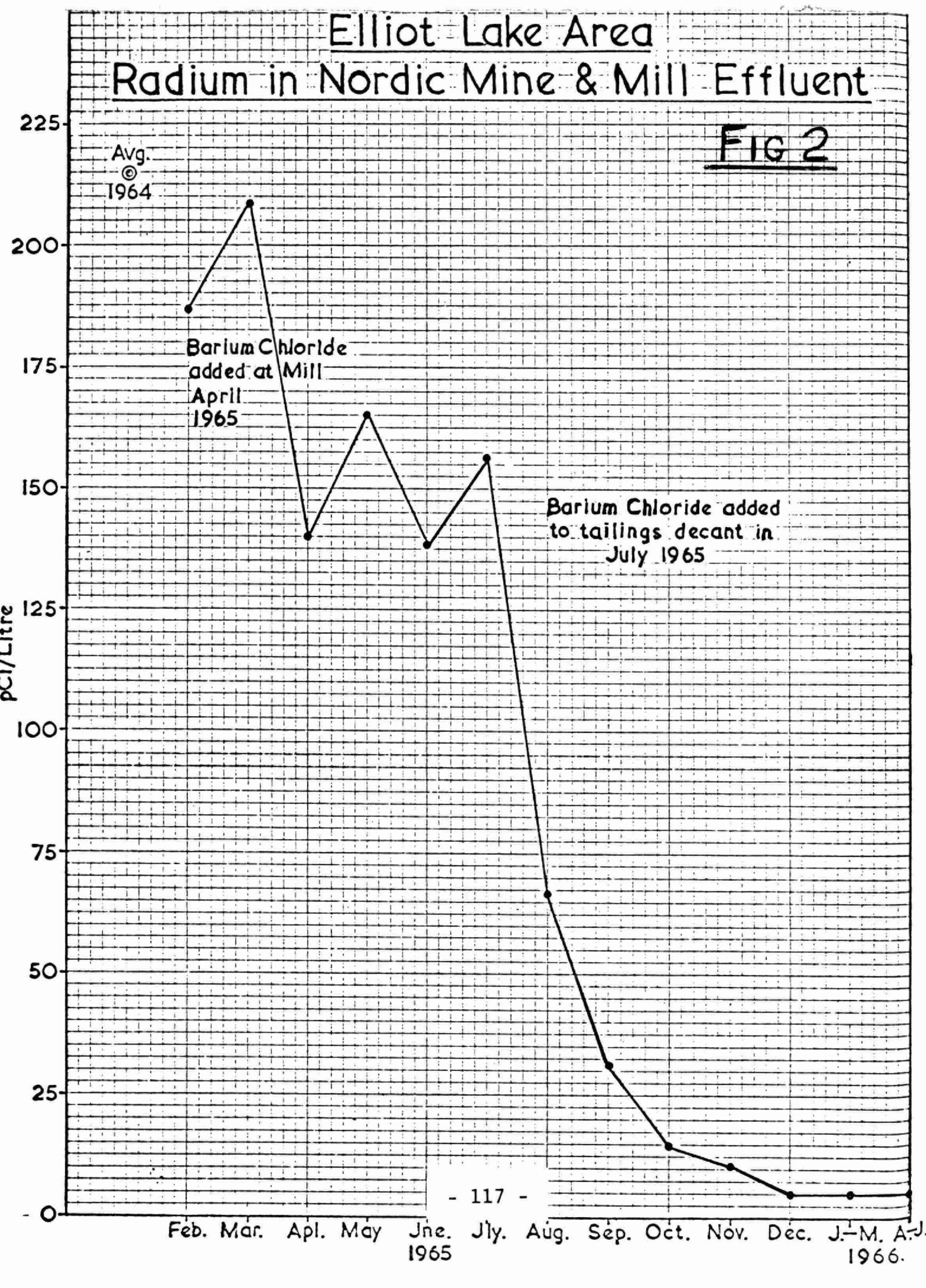
CROTCH
LAKE
5C
McCABE
PENELOPE L.
P
STANLEIGH
(CLOSED)
MILLIKEN MILL
CK.
SHERIFF L.
17
SHERIFF
MILLIKEN
(LEACHING)
(CLOSED)
LAC NOR
DUMBELL L.
ELLIOT LAKE
HORNE LAKE
DAM
5TC
WESTNER L.
ELLIOT LAKE TOWNSITE
3 DAMS
WATER SUPPL
NORTH NORDIC L
ALGOM NORDIC
(OPERATING)
CREEK
RYAN L.
PORRIDGE LAKE
108
BUCKLES
11C
ANGEL LAKE
BAWDEN LAKE
NORDIC
TP 149

Figure 1 illustrates a chief improvement. The curve indicates the radium readings of tap water taken from Elliot Lake which is the site of the Town bearing the same name; its population is about 8,000. The main source of radium was by way of the Sheriff Creek, which flows between the mill and minesite of Milliken Mine. This mine operated continuously from March 1958 to July 1964 and then continued recovery of uranium from underground leaching operations until September 1965. Main measures of control implemented to eliminate pollution were stringent controls against inadvertent spillages of mine and mill water into Sheriff Creek and major diversion of the creek to bypass an accumulation of waste rock fines that had escaped during pipeline failures and settled in a swamp. The diversion was completed in January 1965. The pipeline carrying tailings was also later rerouted to another basin to eliminate the possibility of further leakages.

Figure 2 illustrates the effectiveness of improved settling of solids in the tailings impoundment at the Nordic Mine where the clear overflow of mine and mill solutions is supplemented with 0.01 gms/litre or less of barium chloride. This was begun at the end of July 1965, following extensive laboratory tests. Previous attempts to apply barium to neutralized tailings slurry, before leaving the mill, proved unsuccessful. Apparently barium chloride acts as a leaching agent on radium in fine suspended solids but coprecipitates as barium-radium sulphate when added to clear solution containing dissolved radium. A settling basin has been excavated to confine the precipitate in a small area.

The water from the Quirke Mine which had been flooded since 1961 was pumped out during the past winter at a rate of over 8,000 tpd. Uranium was precipitated and recovered in the mill by neutralization with caustic and lime. The effluent was treated with barium chloride (0.01 gm/1) and then pumped to a tailings basin where the barium-radium sulphate settled. The clear overflow decanted into a swamp and joined a stream which flows into Quirke Lake.


Elliot Lake Radium in Drinking Water.
FIG 1
MPC — 10 pci / litre.
10
5
0
58
59
60
61
62
63
64
65
J
F
M
A
M
J
J
A
S
O
N
D
J
F
M
A
M
J
1965
1966



Elliot Lake Area
Radium in Nordic Mine & Mill Effluent
FIG 2
Avg. © 1964
Barium Chloride added at Mill April 1965
Barium Chloride added to tailings decant in July 1965
pCi/Litre
225
200
175
150
125
100
75
50
25
0
Feb. Mar. Apl. May Jne. Jly. Aug. Sep. Oct. Nov. Dec. J.-M. A.-J.
1965
1966.

Table 1 illustrates the effectiveness of neutralization and barium treatment in removing radium. The increase of the low concentration in the tailings pond, indicated in readings at the dike, probably was due to leaching where the water at the end of the pipeline stirred up a section of old tailings. This effect disappeared in about one month. The pipeline was extended into open water in February, 1966 to prevent any further leaching.

TABLE 1 - TREATMENT OF QUIRKE MINE WATER WITH BARIUM

pCi of Radium per Litre

Date	Mine Water	Mill O/F Before $BaCl_2$	Mill O/F After $BaCl_2$	Tlgs. decant at dike	Swamp Outlet
Oct. 5/65	67				
Oct. 27/65		37			
Nov. 3/65				14	38
Nov. 4/65	97	20	0.7	13	36
Nov. 9/65	131	29	1.1	21	15
Nov. 16/65	121	32	0.9	13	7.5
Nov. 23/65	122	31	0.9	12	7
Nov. 30/65	95	20	0.5	7	4
Dec. 7/65	115	32	1.2	3.3	5.3
Dec. 14/65	103	11	1.0	2.5	4.1
Dec. 21/65	110	--	1.3	2.3	4.7
Dec. 28/65	130	14	0.6	1.5	5

Radium in effluents from both Rio Algom's Nordic and Quirke mines is now well below the Committee's objective of "30 to 10" pCi/l[4].

Extensive information on the monitoring and leachability of radium from tailings discarded from uranium mills in the western United States has been described by Tsivoglou and Shearer and Lee. Considerable information was obtained by reciprocal visits and discussions with the first two authors mentioned and officials of USAEC and of several mills in the Colorado Plateau area. Treatment of effluents with barium was also observed there.

MONITORING OF EFFLUENTS AND PUBLIC WATERS

Regular samples are taken of: drinking water, tailings, tailings dam overflows and of lakes and streams in the surrounding watershed. The monitoring program is specified jointly by the departments of Health and Mines and the Ontario Water Resources Commission. Radiological determinations are made at the Radiation Protection Laboratory of the Department of Health.

DEVELOPMENT OF SHORT METHOD FOR MEASURING RADIUM IN WATER

The standard procedure for measuring concentrations of radium in water used at the Radiation Protection Laboratory involves a waiting period of about one month in order to achieve accurate readings. This has resulted in many delays in the assessment of control measures both in the mine laboratories and in the recovery process.

During the past year attempts have been made to make approximate measurements of radium in water by adapting instruments used in the mine for routine sampling for airborne radiation. The method being used at present is quite simple. A sample is filtered through a two-inch membrane filter. Alpha activity from suspended solids caught on the filter are measured after 4 hours with an alpha probe. Barium is added to the filtrate and the solution is again filtered. The alpha activity of the precipitate on the filter is measured 4 hours later. By comparing the determinations made by the conventional method with those of the short method, it has been found that gross alpha readings from the latter bears a reasonably constant relation with the former for samples taken from given sampling sites. Therefore, actual readings can be predicted with acceptable accuracy for control purposes in about 4 hours and involves about 15 minutes of work for each sample.

CONCLUSIONS

1. About 0.25 percent of radium contained in the ore of Ontario uranium mines is dissolved by mine water and mill solutions. A minor amount of further leaching has taken place in some receiving waters

downstream from tailings overflows. This has not resulted in hazardous exposure and corrective measures have been taken.

2. A portion of the 0.25 percent of dissolved radium is precipitated upon neutralization of effluents and settles in the tailings ponds. Treatment of clear overflows with barium chloride has further reduced concentrations of radium to acceptable levels.

3. The quick method of estimating radium in water is useful for assessing control measures.

ACKNOWLEDGEMENT

Most of this text used for publication of the verbal presentation made at the Ontario Industrial Waste Conference is part of a paper, "Radiation Hazards and Control at Ontario Mines" prepared for the Institution of Mining and Metallurgy, London, England, and appearing in its Transaction, October 1966.

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"THE REGULATORY CONTROL PROGRAM OF THE ONTARIO WATER RESOURCES COMMISSION FOR THE MINING INDUSTRY"

BY

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In the fall of 1963 the OWRC, in cooperation with the Ontario Department of Health, carried out a field study of surface water contamination arising from uranium refining operations in the Elliot Lake area. The field study was, by design, a rapid reconnaissance intended to evaluate in a general way the extent and significance of stream pollution by radioactive waste discharges from the uranium mills (1). The obtained data drew the attention of the industries concerned to the seriousness of the problem and to the necessity of developing a program of waste control for the mining industry in general.

Subsequently, a committee of provincial deputy ministers was appointed by the Prime Minister of Ontario to review and report on the radiological problem. Recommendations #3 and #4 of their report, (2) released in the fall of 1965, can be considered as action recommendations and read as follows:

"3. that the Province should continue to work directly with the uranium mining industry to seek practical means for the control of radioactivity and to establish sound criteria for treatment and disposal works and

4. that a detailed investigation of watercourses and waste disposal in both Elliot Lake and Bancroft areas should be undertaken by the Province, and the present program of monitoring and analysis of mine and mill wastes, surface waters and drinking water supplies, be expanded and extended on a long-term continuing basis."

In keeping with these recommendations, and recognizing also that certain waste controls have already been instituted by the uranium mining industry, including the improvement of tailings disposal areas and the treatment of mine and mill waste waters, a detailed investigation in both Elliot Lake and Bancroft areas is now under way to determine:

(1) the exact extent to which radiological pollution has spread in the watercourses in the two areas;

(2) the extent and importance of all radio-isotopes that are known or suspected to be present in the mine waters and mill wastes;

(3) the control measures that may be taken by the mining industry to prevent further physical, chemical, and radiological pollution from all active and inactive uranium mining operations.

An aspect of future control programs that is recognized by both the industry and the regulatory agencies (OWRC and Atomic Energy Control Board) concerned is that any steps taken towards the reduction of the dissolved radium will have been to no avail if the radioactive solids (tailings) are not permanently controlled. This is readily appreciated when one considers that the half-life of radium is 1,620 years.

A statement issued by the U.S. Public Health Service in May, 1964 (3), concering the ultimate disposal of

uranium mill tailings in Colorado, reads as follows and can be applied to the Ontario situation: "... to determine the degree of hazard associated with these tailings piles is no simple problem. If you think in terms of immediate hazards, or in terms of hazards this year, it is very difficult to show that there is a problem. What has concerned us right along has been the long-lived nature of the radioactivity involved."

Because tailings control is not only a problem of the uranium mining industry, but one that has to be faced in all mining operations (metal mining primarily and, to some extent, industrial), it became evident, as the government dealt with the uranium mining problems, that in addition to chemical treatment of waste flows from operating mines, a code of waste control and disposal criteria for tailings disposal and embankment design was required to provide some guidelines for mining companies now operating in the Province or that may come into production in the future. During the deliberations of the Deputy Ministers' Committee, schedules of control criteria in other similar jurisdictions, e.g., United States, and their implementation, were reviewed and found to be practicable. Such factors as site location, embankment design (including side slope ratio, freeboard, seepage control, top width, foundation characteristics and protection of embankment surfaces), construction methods, and specifications, have been incorporated into a published schedule developed by the U.S. Atomic Energy Commission in cooperation with the U. S. Public Health Service (4).

In keeping with the control program suggested in Appendix IV of the Deputy Ministers' Committee report, a set of design principles for the construction and maintenance of tailings ponds was adopted and published by the Commission (5). A copy of this guide is attached (as Appendix "A") to this paper.

It is the purpose of this guide to specify in detail the information which the Commission will require in connection with the issuance of certificates of approval

for industrial waste treatment works specifically related to tailings disposal areas, and to identify the criteria for their construction and maintenance that will be used in evaluating such systems. The criteria are necessarily general in nature since the characteristics of embankment systems may vary significantly from one location to another.

These design principles are also applicable to other industrial disposal problems that require the design of waste ponds for the storage of liquid, semi-solid,or solid waste materials.

RECOMMENDED CONTROL MEASURES

The principal characterization of mining wastewaters is their settleable solids content. This comes about because most ores contain from 1 to 10 percent of the desired concentrate, (less than 1 percent in the case of uranium ores), hence the bulk of the feed to a mill must be discarded. The milling of uranium ores alone in the Province of Ontario has resulted in the accumulation of over 50 million tons of solids in tailings ponds at Elliot Lake and Bancroft. This represents the mill discharge from fourteen mining enterprises operating on the average for considerably less than ten years. Only three of the original 14 are active today; thus, the waste tonnage from this industry alone demonstrates the problem of designing dyke systems to ensure permanent confinement of these waste materials.

Where chemical reagents are used, such as in froth flotation processes or leaching operations, these reagents and water soluble products in the case of leaching can further add to the characteristics of any particular mill wastewater stream (radioactivity nitrates, sulphates, hardness, etc.).

The beneficial effects of the use of tailings ponds as a form of waste control are:

(1) the removal of settleable solids and some limited evaporation of liquids, and

(2) the permanent retention of waste materials in well-defined areas if the impoundment basins are properly designed and maintained.

Undesirable features of some tailings areas are:

(1) the inherent porosity of the tailings which permits seepage laterally or vertically;

(2) the opportunity for extensive contact between the liquid and the tailings which, in the case of uranium mines, can lead to the leaching of radioactive contaminants;

(3) the observed tendency to fail structurally and release their contents if the dam walls and decant structures are not properly constructed and maintained. This third feature of failure may be divided into three types according to different causes, as follows:

   (i) Surface erosion - Material is removed from the outer surface of the dam wall by rainfall, runoff, and wind erosion. This is clearly shown by the formation of gullies on the outer slopes.

   (ii) Seepage problems - Water which has collected behind the dam wall seeps through the wall and emerges at the toe of the wall, causing weeping and undercutting of the walls.

   (iii) Shear failure or "breakaways" - These occur when the shear strength of the dam material, or of the foundation soil, is too low, with the result that a large portion of the wall tears away and sluices out onto the adjoining ground.

In the mining industry in general, the existing methods of building tailings dams have evolved on the basis of experience gained by trial and error. Until recently, there have not been many attempts to use a

scientific basis for their design. Some general comments on the three types of failure mechanisms are as follows (7):

(1) Surface Erosion

Since the agents causing surface erosion, namely wind and rain, are not subject to control, its prevention must be based on the material used for dyke construction, the method of construction, or the growth of vegetation. On some dams a hard outer crust will form which is resistant to surface erosion. The formation of this crust is attributed to the products formed on the decomposition of iron pyrites which may be present in sufficient amounts in certain waste tailings.

The placing of rock riprap, or other material, on dykes to protect them from erosion is an accepted control measure by the mining industry and can be very effective, providing sufficient waste material is available.

The lack of plant food and the unsuitable pH conditions encountered with most tailings pile materials make it difficult to establish vegetation directly on dyke walls.

Some success by Hollinger Consolidated Gold Mines Limited at Timmins, and the International Nickel Company at Sudbury, as well as some South African gold and uranium mines, is documented, (8), (9), and (10), and the OWRC is encouraging the mining industry in general to set up experimental plots on existing accumulations of tailings to see under what conditions vegetative cover can be developed.

(2) Seepage Erosion

Behind most tailings dams there will normally be a pond of water, and, as most dams are permeable unless specifically constructed to eliminate this characteristic (unusual in the industry due to cost and lack of suitable construction material), water from this pond will seep into the dam walls. The presence of

seepage water in the foundation soil under dam walls will always result in buoyant uplift pressures within the slope, thus reducing the shear strength of the materials and lowering the factor of safety against sliding.

The flow pattern of this seepage water through a dam wall will be governed by the ratios of permeabilities of the different layers of material through which the seepage water passes, the relative thickness of these layers and the drainage conditions of the site. Typical examples of flow patterns for a given set of seepage conditions are shown in Figures 1 and 2. The phreatic line is the upper limit of the seepage zone.

In the case of Figure 1, the flow net for an impermeable base is shown, and, as the seepage water cannot enter the foundation soil, it finds its way out through the toe of the dam. This condition is encountered frequently in the hard rock country of Northern Ontario.

The opposite case is shown in Figure 2, where the foundation soil is very permeable and the water table is deep, resulting in all seepage water passing straight down into the foundation soil without wetting the walls, thus allowing the dam to remain dry and stable.

In Figure 1, the dam wall will be saturated and thus weakened, and there will be weeping at the toe and possible erosion or under-cutting.

Problems with seepage can be expected in cases where:

(a) the foundation soil is relatively impermeable solid rock, clay or sandy clay;

(b) the natural drainage conditions are bad, e.g., water-logged ground, or where the water table is high.

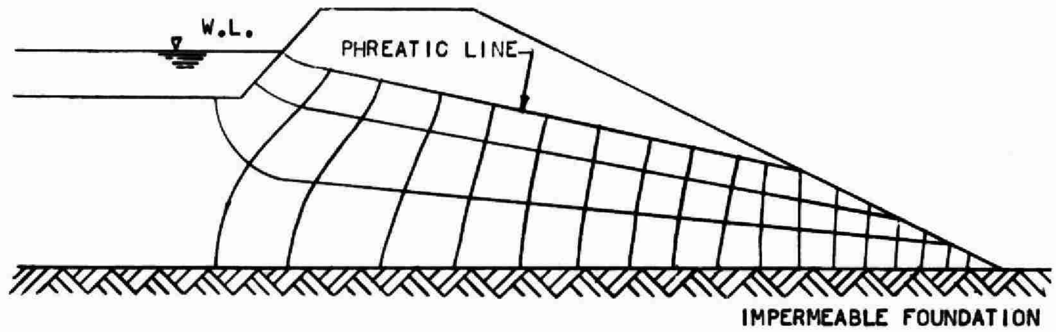

FIG. 1 FLOW NET FOR A SLIMES DAM WITH AN IMPERMEABLE FOUNDATION

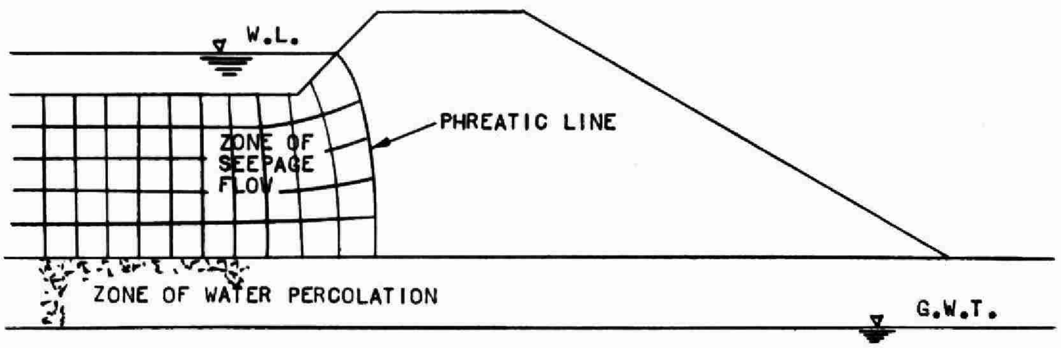

FIG. 2 FLOW NET FOR A SLIMES DAM WITH INFINITE SUBSURFACE DRAINAGE

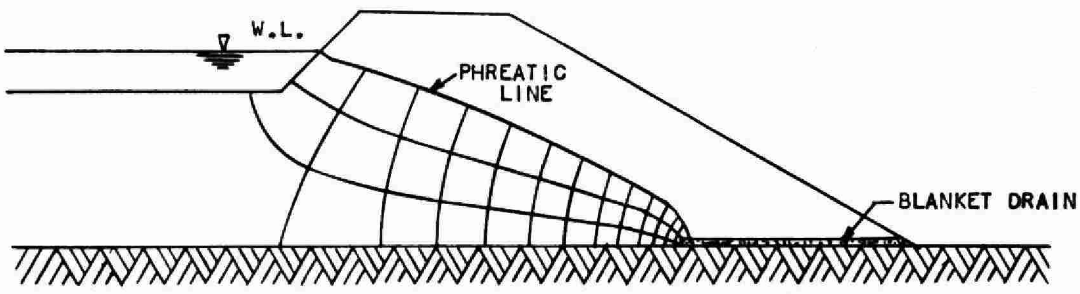

FIG. 3 FLOW NET FOR A SLIMES DAM WITH A BLANKET DRAIN

Since in the mining industry it is not always possible to build tailings dams on areas having good drainage, or to have a readily available source of clay to build an impervious corewall the provision of artificial drainage must be considered. The artificial drain should be designed to draw off the seepage water inside the dam and to bring it out through the wall without endangering the stability of the dam. The effect of an adequate drain on the position of the flow net is shown in Figure 3.

Three points in the design of a drainage system should receive attention:

(i) the drains must be designed to pass the total amount of seepage water;

(ii) the drains must be protected against clogging;

(iii) the drains must be located so as to give the greatest protection to the dam.

A typical example of a possible drain system for a poorly drained land area is shown on Figure 4. For areas where seepage is likely to be small, a rock-toe drain as shown in Figure 5 will probably be adequate.

If attempts are made to solve a seepage problem by building a buttress of classified tailings or other material against the dam wall, within a short while the buttress will also be subject to seepage problems as shown on Figures 6, 7, and 8.

The recommended method of treatment is either to place a buttress of earth or tailings with under-drains, Figure 9, or to place an open rock buttress with filter layers as shown in Figure 10.

(3) Shear Failure

Shear failure on an embankment occurs as a section of the embankment slides on a curved surface which, for the sake of simplicity in stability analyses,

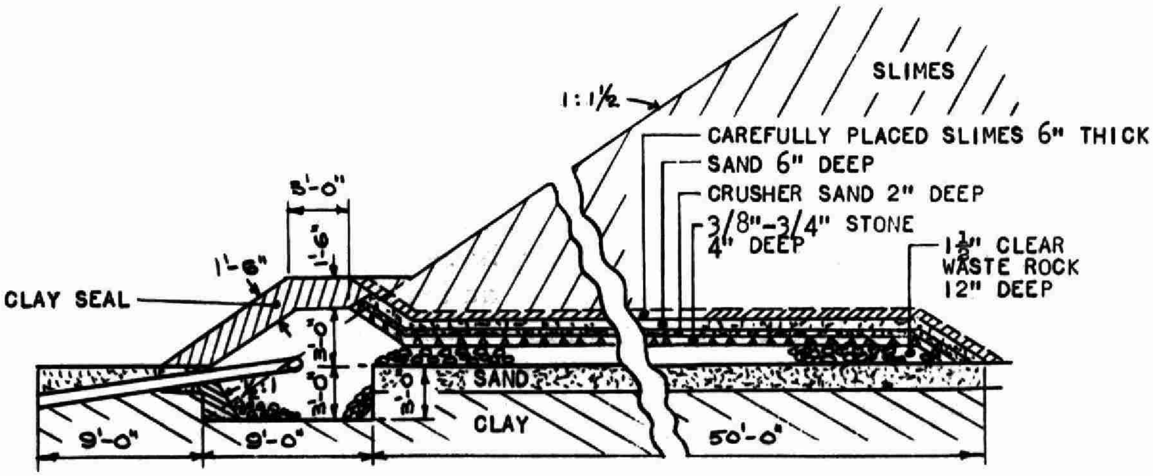

FIG. 4 BLANKET DRAIN WITH FILTER LAYERS

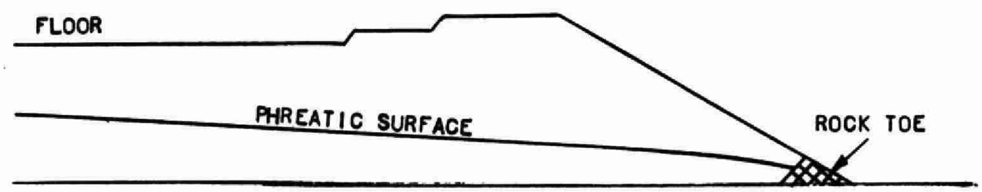

FIG. 5 CONTROL OF SEEPAGE FLOW
BY MEANS OF ARTIFICIAL DRAINS

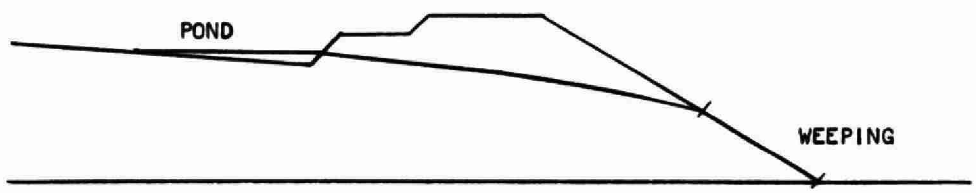

FIG. 6

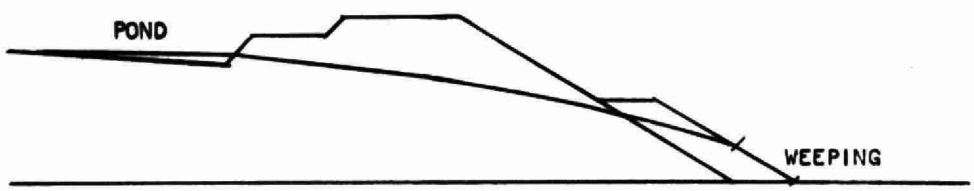

FIG. 7

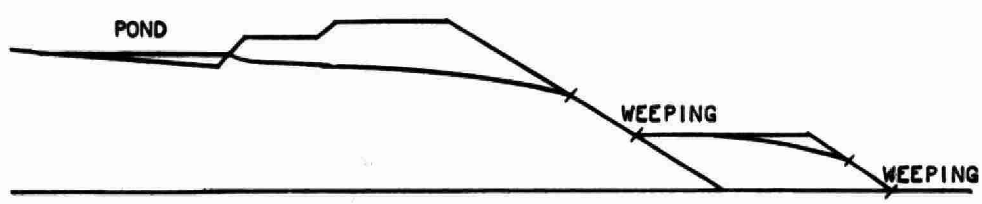

FIG. 8

FIG. 6, 7, &8 SEEPAGE PROBLEMS ON EXISTING SLIMES DAMS

is assumed to be a circular arc. The failure surface may pass through wall material only or may also pass through the foundation soil, as shown in the series of possible failure arcs in Figures 11 and 12.

It is generally assumed that deposits of waste solids have similar physical characteristics to those of certain soils and that the physical shear strength of the material may be determined by standard tests used for earth materials. Thus, the allowable side slopes and final height of a waste pile may be determined in the same manner as in the design of an earth dam.

If a dam wall is too narrow for the height of the dam, the probable failure surfaces will pass through very little wall material and will be contained mainly in the weaker material laid down under water on the floor of the dam. If the walls are wide enough, the probable failure surface will be contained within the strong wall material.

A point that deserves some comment when dealing with control measures to improve tailings impoundment basins is that problems with seepage erosion and shear failures often will arise because of the method selected to feed a dam. It is still common practice at most mines to use single-point entry for the waste flow. This practice results in high and low ends in the dam with a consequent tendency for the pond to be forced towards the lower end. The result is generally that the line of seepage is raised at the lower end of the dam which contains the higher portion of material having clay-like properties, i.e., little intergranular friction, and also often is the location of the decant tower. Thus, in case of a breakout, or tower failure, this area is ready for liquefaction and in one case at a mine in the Elliot Lake area, 500,000 tons of tailings were lost when a decant tower shifted off the concrete tunnel which conveyed the clarified effluent off through the base of the dam.

Wherever possible, the decant tower or weir-controlled outfall device, which permits the level of water behind a dam to be raised or lowered as the

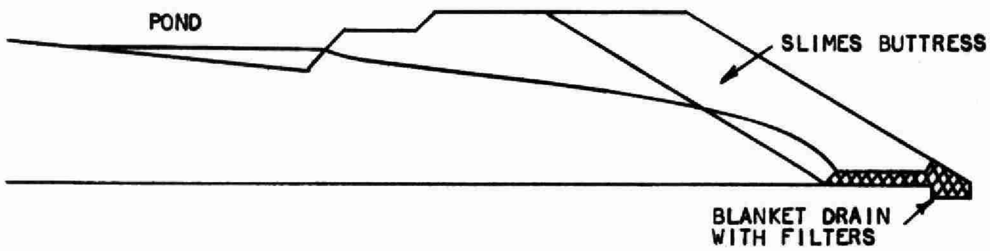

FIG. 9

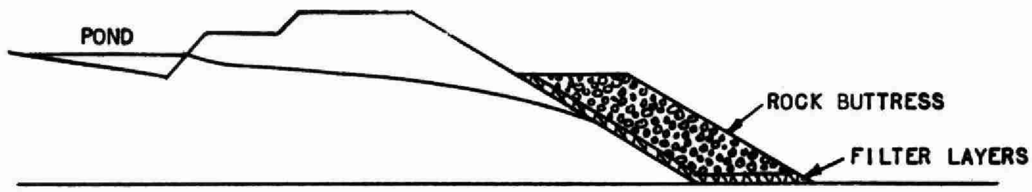

FIG. 10

FIGS. 9 & 10 RECOMMENDED METHODS OF PROTECTING THE TOE OF AN EXISTING SLIMES DAM SUBJECT TO SEEPAGE EROSION

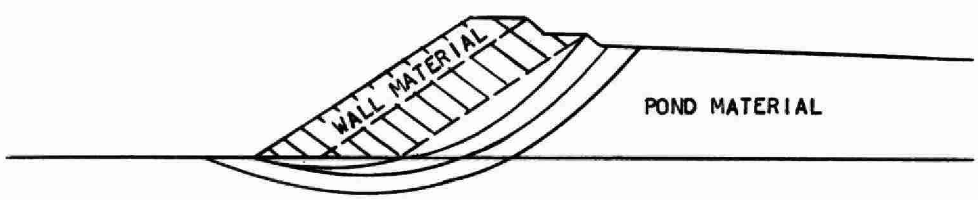

FIG. 11

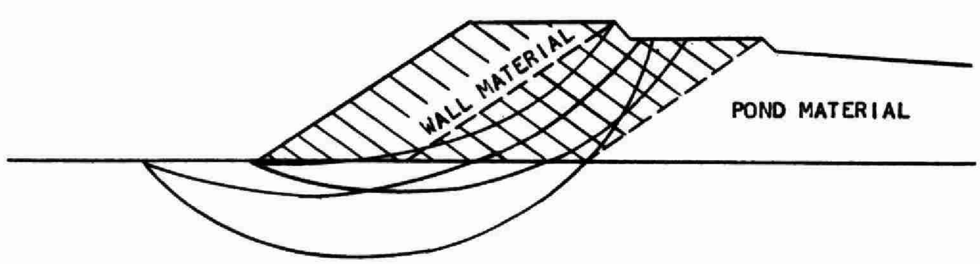

FIG. 12

FIGS. 11 & 12 THE INFLUENCE OF WALL THICKNESS ON THE STABILITY OF A SLIMES DAM

settling characteristics of the suspended matter in the wasteflow dictate, should be located on a well-drained area and remote, if possible, from the dam walls. At all times the size of the pond around a decant facility should be kept to the minimum level required to achieve a clear water discharge, thus minimizing hydrostatic pressure on the adjacent dykes, and aiding in the prevention of seepage problems.

To overcome this disadvantage of single point entry it is recommended that piped feed points be established around the periphery of tailings dams to permit a form of a "dribble system" to be established at intervals along the pipeline. This form of feeding ensures that a beach of even width containing the coarser sands will be formed around the pond adjacent to the dam walls, and eases the problem of keeping a pond of water evenly distributed around a decant system which is of necessity set back in the pond proper. When the peripheral area adjacent to the dam wall, on which the large tailings pipe sits, is filled with coarse sands, these are bulldozed, or lifted, back to increase the height of the wall and the tailings pipe is then raised to sit on the newly created dam wall. For such multipoint feeding systems the cost of piping is higher, but this has to be weighed against such factors as the improved stability of the dam walls and the extra dam height that can often be obtained.

A point that is also worthy of mention is that neatness is an important factor to be considered in basic design planning for any impoundment basin. A waste holding pond and its discharge system can seldom be scenic, but an orderly appearance can be achieved. In the case of abandoned tailings basins, consideration must always be given to the long-term control and aesthetic benefits to be derived from landscaping or levelling the area and attempting to bring about the growth of some natural vegetative cover.

Experiments and attempts by the International Nickel Company of Canada Limited at stabilizing the tailings area over the years have seen many different projects undertaken, including windbreaks of willow

trees, snow fencing, water spraying, oil spraying, dressing slopes with slag, both crushed and granulated, mulching with straw, and using pyrrhotite spray.

However, on the basis of findings to date at Inco and at mining companies in other countries where extensive experiments have been carried on, it appears that vegetation is the best practical answer to the problem of permanent tailings stabilization. The cost of seeding at Inco ranges from $250.00 to $300.00 per acre.

The existing methods of building dams to impound mine wastes have evolved over many years of experience gained by trial and error, but often lack a scientific basis for their design. So often a dam is built on a site which has no merit other than that it is not required for any other purpose. To have a sound and stable tailings dam, enclosing a suitably-sized area should be important to a mine and the best site should always be chosen.

SUMMARY

The increased surveillance being given to the pollution of streams and spoilation of lakes and surface areas adjacent to large mining developments demands that the building of dams to impound waste materials be given much greater study than it has received in the past.

APPENDIX "A"

INFORMATION REQUIRED AND CRITERIA USED TO EVALUATE EMBANKMENT RETENTION SYSTEMS DESIGNED TO IMPOUND SOLID WASTE MATERIALS DISCHARGED AS SLURRIES

This guide has been prepared as an aid in the preparation of applications for approval of industrial waste treatment and disposal systems in which embankment or impoundment is used to prevent or control the discharge of suspended solids.

This is not intended as an interpretation of Commission policy within the meaning of Section 27 and 50 of the Ontario Water Resources Commission Act, nor as indicating that applications which follow the recommendations of this guide necessarily will be approved.

INTRODUCTION

The processing of unrefined ores, particularly the milling of gold, uranium and base metal ores, produces large quantities of liquid and solid wastes (tailings) which contain concentrations of suspended solids and toxic ions in excess of OWRC objectives for discharge to surface waters in Ontario. It is therefore, necessary to impound these wastes, such that their discharge to surface waters is controlled or prevented. Impoundment is usually accomplished by the construction of dyked retention systems with a controlled decant to a surface water. The advantage of this system, apart from pollution control, is that solids are retained for reprocessing, and, in cases where an abundant water supply is not available, the decant can be re-used in the mill circuit.

The size and construction of these retention systems will vary with the production capacity of the mill, the volume of liquid waste produced, the topography of the area and the availability of land for a disposal site. Generally, the location of a retention system is chosen to take advantage of the natural contour of the area, but it is usually necessary to construct an earth and/or tailings dyke at some point to contain the liquid or solid wastes, or both. In the latter case, the liquid and solids are usually discharged to one area within the system so that coarse solids build up in essentially the same area, and the fine solids or slimes and liquids flow toward the centre of the tailings pond area. Tailings embankments are usually constructed by discharging a tailings slurry near the inside edge of the initial earth embankment. The coarse solids rapidly settle out near the initial embankment and the fine solids drain to the centre of the system. When tailings accumulate to within a few feet of the top of the embankment, the system is extended by depositing coarse

solids on the top of the embankment.

It is important that these embankment retention systems be constructed and maintained in accordance with sound engineering principles in view of their purpose to prevent or control the release of objectionable constituents to the receiving stream environment. The Commission has proposed criteria for the construction and maintenance of these earth and tailings embankments, which are principally derived from the requirements of the United States Atomic Energy Commission for the licensing of disposal systems for uranium ore processing wastes.

It is the purpose of this guide to specify in detail the information which the Commission will require in connection with the issuance of certificates of approval for industrial waste treatment works specifically related to tailings disposal areas, and to identify the criteria for their construction and maintenance that will be used in evaluating such systems. The criteria are necessarily general in nature since the characteristics of embankment systems may vary significantly from one location to another. However, these criteria should not be considered as relieving an applicant of his responsibility for ensuring that his system is adequate from a structural and pollution control standpoint.

The Commission may request additional information from applicants if such information is necessary to provide reasonable assurance that the applicant has established an adequate system. Such requests may be avoided by a thorough study of Commission objectives and this guide prior to submission.

An applicant may incorporate, by reference, information contained in applications, statements and reports previously filed with the Commission's Division of Industrial Wastes, provided that such references are clear and specific.

INFORMATION REQUIRED

In addition to the information required by Section 31 of the OWRC Act, as outlined in the application form, the following information should also be included:

(a) Drawings showing the layout in plan; typical cross-sections of all embankments showing showing proposed design, and if applicable, anticipated future extensions; and other pertinent design details. Embankment design should include information on heights, top width, side slopes, freeboard, seepage control, and protection of embankment surfaces as well as foundation design.

(b) A design analysis of the integrity of the proposed system including, as applicable, the results of soil tests, geologic exploration, nature of foundation materials, stability investigations and characteristics of fill material as well as a description of the construction methods and specifications.

(c) An evaluation and discussion of conditions that might lead to accidental release of the waste, the probable environmental effects of such release, and proposed program of inspection and maintenance to prevent such an accidental occurrence.

EMBANKMENT RETENTION SYSTEM CRITERIA

The Commission will take the following factors into consideration in evaluating for approval, the information submitted by an applicant:

A. Location

1. The site should be subject to the complete control of the applicant so as to permit entry only of authorized personnel thereto.

2. The site should not occupy the channel of any permanent watercourse unless a provision has been made for permanent diversion of such

watercourses around the site.

3. The site should be permanently protected against runoff from the surrounding drainage area by the provision of diversion channels to prevent such runoff from entering or washing out the embankments.

4. A minimum distance of 200 feet should be maintained between the embankments and any permanent flowing watercourse at flood stage to minimize percolation effects, unless information is submitted for satisfying a closer location.

B. Design

1. Foundations - Foundations should be investigated to determine that they have suitable strength and permeability characteristics for the embankment proposed, including anticipated future extensions. A foundation of rock or graded sand and gravel is normally considered to have satisfactory strength for small embankments (under 25 feet in height). Foundations of alluvial deposits, which have not been consolidated under appreciable loads, and those of fine and uniform sands, or of plastic clays, must be given careful investigation and treatment to ensure safety of the embankment.

2. Embankments

(a) Construction material - The embankment material used in the construction of earth embankments may be natural soil, usually barrow soil found nearby, suitable for the construction of such systems. Coarse tailings material may be used to extend an earth embankment provided design and construction methods specified in this guide are followed.

(b) Top width - The minimum top width of an embankment should be eight feet. As the height of the embankment increases, the top width should be

increased as specified in Table I below. It may be necessary to further increase the top width if the embankment material is susceptible to erosion or sloughing.

TABLE I - RECOMMENDED MINIMUM TOP WIDTH FOR EMBANKMENTS

Height of Embankment (feet)	Minimum Top Width (feet)
8 to 12	10
13 to 20	12
21 to 30	15
Over 30	20

(c) Side slopes - In most cases, the type of material that is readily available for embankment systems will require that side slopes on the upstream face (i.e. in contact with the liquid) have a slope ratio between 4 to 1 and 2½ to 1, and on the downstream face of the embankment between 3 to 1 and 2 to 1. Table II below contains recommended maximum slopes for embankments constructed of various materials.

TABLE II - RECOMMENDED HORIZONTAL TO VERTICAL SIDE SLOPE RATIOS FOR EMBANKMENTS

Embankment Materials	Upstream Face	Downstream Face
Homogeneous Sandy Clay	2½ to 1	2 to 1
Coarse Sand with compacted clay or structural core wall	3 to 1	2½ to 1
Sand-gravel mixture with compacted clay or structural core wall	3 to 1	2 to 1
Homogeneous Sandy Loess	3 to 1	3 to 1
Homogenous Silty Clay	4 to 1	3 to 1
Coarse Tailings (dry)	2½ to 1	2 to 1

Where coarse tailings material is used to increase the height of an initial earth embankment, the Commission will consider the material as purely frictional with an angle of internal friction of 33 degrees (i.e. a natural slope of approximately $1\frac{1}{2}$ to 1). This will mean that the downstream face of the embankment should have a total slope ratio of approximately 2 to 1. Berms may be employed in the construction of the embankment to satisfy this side slope ratio,, provided the berms are at least eight feet in width, the height of each embankment section does not exceed 18 feet, and the slope of each tailings embankment section is at least the natural slope of the material. The recommended slopes in the above table may have to be flattened when necessary to spread the load so that the maximum unit stress induced in the foundation will be less than the shear strength of the foundation material or when full knowledge is not available on shear strength and seepage flow.

(d) Freeboard - The freeboard height of the embankment above the maximum liquid level should not be less than three feet. Consideration should be given to future compaction and settlement of the embankment and to frost penetration which would materially effect the possible freezing and cracking of the embankment above water level.

3. Seepage Control - Suitable methods should be employed to minimize the effect of seepage on the embankment and its foundation. Methods of controlling seepage include toe drains, filter layers, impervious cut-offs or blankets, and corewalls. Seepage along the contact surface between the foundation and the embankment should be minimized by removal of all organic material such as sod and top soil, and where appropriate, the installation of a "key" trench.

4. Protection of Embankment Surfaces - Embankment surfaces should be protected against erosion by the use of such means as vegetation, berms, logs, or riprap. The method of protection used must be based upon the susceptibility to erosion.

5. Protection Against Environmental Release - Where deemed necessary, provisions such as the use of additional surrounding embankments or sumps should be made for capturing or holding liquid waste resulting from seepage through the embankment or unexpectedly released by failure of the primary embankments.

   Unprotected surfaces on the top or within the retention system, such as inadequate crust formation, should be provided with an effective means of dust control, such as a sprinkler system for periodically wetting down these surfaces, a form of cement or asphalt binder for a more permanent sealer of the surfaces, or vegetation if found feasible.

C. Construction Methods

Construction of the embankment should be started only after clearing and grubbing operations are completed and the foundation has been properly prepared. Embankment material should be free of sod, roots, stones over six inches in diameter, and other material which might interfere with proper compaction. Frozen material should not be placed in embankments and embankments should not be constructed on frozen foundations. The placing and spreading of embankment material should be started at the lowest part of the section under construction and the embankment carried up in horizontal layers not exceeding eight inches in thickness. Insofar as possible, these layers should be of uniform elevation and extend over the entire area of the fill. The distribution and gradation of materials throughout the embankment should be such that there are no lenses, pockets or streaks created, and the moisture content of the materials should be proportioned for maximum degree of compaction. Proper compaction of the embankment

material should be achieved by the use of equipment designed for this purpose, usually a sheepsfoot roller. The travel of excavating equipment is generally not considered an adequate method for obtaining compaction. If the sheepsfoot roller is used, it should be weighted to give a unit pressure of not less than 200 pounds per square inch of the total surface area of the feet simultaneously in contact with the embankment. Usually six passes of the roller over each individual layer of material are sufficient to obtain good compaction. For relatively low embankments, under 25 feet in height, the adequacy of compaction may be determined by observation of the roller in action. For embankments over 25 feet in height, field control over compaction should be more precise and the embankment should be rolled until some predetermined degree of compaction is obtained, usually 90 to 95 per cent of maximum density as determined by appropriate compaction tests.

Tailings embankments should be started with an initial outer earth embankment as described above and may be raised when necessary by using coarse tailings materials. The tailings, usually in the form of a slurry, should be deposited within the system in such a way that coarse sands settle out first near the embankment, while the fines or slimes are carried away toward the liquid pond area where the liquid is retained. Observations should be made and records kept of the deposition of tailings as well as sampling of the tailings near the embankment to determine its properties for use in building up the embankment. In order to gain the maximum shear strength from this material, it should be kept as dry as possible during embankment extension and all subsequent seepage flow should be minimized. Proper construction methods, including compaction, should be observed as specified above.

D. Maintenance and Inspection

A program of maintenance and inspection should be established to detect and repair environmental and other effects which might tend to lessen the integrity of the embankment system.

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"ENGINEERING ASPECTS OF PROBLEMS IN THE AQUATIC ENVIRONMENT RELATED TO EXCESSIVE NUTRIENTS"

BY

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Water pollution control is entering a new phase. For these many years, the major concern has been with limiting the amounts of organic matter discharged to receiving waters so as to maintain reasonable dissolved oxygen levels for the support of fish or, at least, for the avoidance of the production of obnoxious odours.

Over the course of the years many observers have noted that treatment of waste waters for the removal of organic matter to satisfactory levels did not always insure that the quality of the receiving waters was not impaired. A major complaint has been related to the development of excessive plant growths, algae and rooted aquatics, which have given rise to offensive conditions or otherwise impaired the use of the waters. Gradually, it has been established that the magnitude and extent of these plant growths are related to the degree of fertilization of the aquatic area involved. In other words, aquatic plants respond to the same stimuli as do land plants.

Studies have shown that waste water treatment plants designed to remove and destroy organic matter do little to remove the fertilizing matters, nitrogen and phosphorus, so essential to plant growth. This is particularly true of treatment plants employing anaerobic digestion as a means of sludge disposal.

The literature is replete with articles which describe the degradation of lakes and reservoirs because of excessive fertilization due to domestic and industrial waste water discharges. These problems were first recognized in Europe and a summary describing some of the cases was published by Hasler[1]. The situation which existed in the lakes at Madison, Wisconsin, is quite notorious and was studied extensively by Sawyer[2]. Lake Washington at Seattle has received considerable attention because of its gradual degradation due to waste water discharges as the city and its suburbs grew in size[3]. Other areas with problems which have received some publicity or study are: Lake Zoar in Connecticut[4], Detroit Lakes in Minnesota[5], Lake Winnisquam in New Hampshire[6], Spring Creek in Pennsylvania[7], and Boston Harbour[8].

In the light of our present state of knowledge, it is quite generally conceded that the biological productivity of any body of water is directly related to the degree of fertilization by plant nutrients. For this reason the term - "nutrient problem" - has come into use and those concerned with water resources of the future are giving more and more attention to it. It is this concept, plus a growing realization that serious deterioration of lakes and reservoirs occurs rapidly once the process starts, that has led to the inauguration of preventive programs in some areas. A notable example is at Lake Tahoe[9] where domestic waste waters are to be given extensive tertiary treatment to remove prime nutrients in order to avoid unnecessary fertilization of the lake. Increasing attention is being given to the Great Lakes presumably for the purpose of preventing eutrophication and degradation of those great bodies of water[10].

At this stage in our discussion, it would be easy but erroneous to conclude that the removal of fertilizing elements from all domestic and industrial waste waters would solve all our problems due to algae and rooted

aquatic plants in our lakes, reservoirs, and streams. Reference to the literature will show that there are some instances where waters with little or no waste waters of human or industrial origin are highly productive of nuisance algal growths. One such lake is Klamath Lake in Oregon[11], another is Lake Okoboji in Iowa. Undoubtedly, there are many others not known to this writer.

It becomes mandatory, therefore, from the engineering viewpoint to study each situation so as to establish the nutrient budget for each body of water and ascertain the amounts contributed from natural land drainage in opposition to that from unnatural sources such as waste waters, which might be brought under control. Once the amount of nutrients originating from the various sources is known, it becomes possible to make an appraisal of corrective measures. Any sound assessment of a given situation involves employment of engineering and analytical chemical skills of a high order.

FLOW MEASUREMENTS

Gauging-The base for the quantitative evaluation of the nutrient budget of any body of water depends upon measurement of the inflowing waters. This is by all means the most difficult aspect of any survey and taxes the ingenuity of the engineer to the utmost.

The discharges of waste waters are in most instances metered, or flow through conduits which are readily adaptable to the installation of gauging devices, so constitute no great problem. The gauging of storm sewer and sewer overflow discharges poses an almost insurmountable problem. Rivers and streams can be gauged in a variety of ways. In any event gauging of tributary rivers and streams seldom measures the total flow, because gauging stations with any degree of reliability require reasonable approach discharge and cross sectional characteristics, plus accessibility. Even under the best of conditions it becomes necessary to measure flow from a part of the drainage area and extrapolate the data to obtain the flow from the total drainage area in any watershed.

Although the use of continuous water level recorders is highly desirable, there are two situations which interfere with their reliability. One is related to varying downstream water levels which may result from weed growths clogging the channel or back waters from varying water elevations in the receiving body of water. The other is related to wind effects which can actually retard or enhance the flow depending upon wind conditions. Reversal of flow can actually occur at times in rivers with a very slight gradient.

Experience will often show that the measurement of flows in relatively small streams is not necessary. This is particularly true if the waters are relatively free of nutrients. Where other streams in the vicinity are under measurement, the flow in the small streams can usually be estimated with a reasonable degree of accuracy, if the drainage area is known.

The reliability of any water level recorder or of a simple staff gauge from which periodic readings are made depends upon the development of rating curves derived from actual stream flow measurements with current meters for the reasons expressed above. A continual program of stream gauging must be maintained to check the validity of the rating curves and develop the necessary correction factors.

Indirect Methods of Flow Measurements - Under some conditions, especially where backwater effects are serious, it may be possible to use the concentration of some chemical component in the water as a means of estimating flows. The writer in his surveys of the Madison, Wisconsin lakes found a relationship between alkalinity and flow on some small streams with relatively small drainage areas[12]. It is likely that other criteria might be used, such as chlorides, hardness, etc., but it is unlikely that the method would apply to streams with large drainage areas, except in unusual cases.

SAMPLING

Ideally, sampling should be done by automatic samples with portions taken at frequent intervals in proportion to the flow. This is impractical for several reasons:

First, such equipment would in most cases have to be battery powered. Second, the equipment would be inoperable under freezing conditions. Third, the equipment and installation would be difficult to protect from acts of vandalism. Fortunately, stream flows do not vary so radically or the chemical content fluctuate sc much that samples need be taken more than once per day, or twice per day at the most. Under low flow conditions weekly sampling may be adequate.

The cost of sampling streams at frequent intervals can often be kept to reasonable levels by hiring some local person to collect samples at the desired intervals. Where staff gauges require reading, the sampler can fulfill this need also. If the samples are properly preserved, they need be collected only once per week for analysis.

The sampling of storm sewers constitutes a real problem, particularly because the first flush of water usually carries the greatest concentration of nutrient materials, mainly due to bird and animal droppings. If this first flush is not sampled, the results are not representative. Furthermore, seasonal variations are quite significant and year round surveys are required. For example, some cities allow the burning of leaves in the street. The ashes are rich in phosphorus and do a great deal to enrich storm waters during the autumn months. Others allow the dumping of leaves along the edge of the street to facilitate mechanical collection. The materials leached from them during storms can add materially to the nutrient content of storm waters.

Where multiple storm sewer discharges occur, which is usually the case, it is impossible to sample all without an army of personnel. It is far better to concentrate on sampling a few representative ones thoroughly and apply the data to the others on a basis of judgment.

CHEMICAL ANALYSES

All of the great effort expended on flow measurements and sampling will be wasted if the samples are not carefully analyzed for those materials of importance to algal growths, i. e., the nutrient elements. Chemical analyses of various forms of algae have shown them to consist mainly of carbon, hydrogen, oxygen, nitrogen, and phosphorus. Certain forms, such as the diatoms, contain appreciable amounts of silica. Minor elements are sulphur, potassium, calcium, magnesium, and iron. Of these elements, most natural waters contain adequate amounts to support intense algal growths, except for nitrogen and phosphorus. Many studies have shown these elements to be critical in the nutrient problem. One of the more recent is the work of Shapiro and Ribeiro[13]. Any analyses of water samples which do not include a complete analysis for all forms of nitrogen and of phosphorus, therefore, will defeat the objectives of a survey.

Nitrogen - Nitrogen exists in natural waters and waste waters principally in the form of ammonium ions, nitrate ions, and organic forms. In some instances it may occur in significant amounts as nitrite ions. Water samples should be analyzed for all forms. The determination of ammonia, nitrite, and organic nitrogen poses no particular problems. The determination of the nitrogen in the form of nitrates does, however, since chlorides interfere seriously when the popular phenol disulphonic acid method is employed. This is particularly significant in the analysis of both domestic and many industrial waste waters because of their relatively high chloride levels. Many analysts do not make corrections for chloride interference, therefore, low nitrate nitrogen values are obtained. The engineer must insist that nitrates be determined by the most accurate method possible in order to obtain reliable results.

Phosphorus - This element exists primarily as ortho phosphate and organic phosphorus in most natural waters and there is usually no reason to analyze for other forms. Because of the use of synthetic detergents, domestic and many industrial waste waters contain complex phosphates in addition to ortho phosphates and organic

phosphorus. Although the complex phospates are measured along with the organic phosphorus they do hydrolyze in water eventually to form ortho phosphate and, therefore, should be measured separately and reported as part of the inorganic phosphorus along with the ortho phosphate. The engineer should insist on having all samples of waste waters analyzed for ortho and complex phosphates as well as organic phosphorus.

DURATION OF SURVEY

The time period over which surveys are run are often determined by the funds available to conduct the studies. Ideally they should continue for a period of at least one year if a good evaluation from natural sources is to be obtained. This is particularly true in areas where drainage from agricultural lands is a significant factor. There are some instances where a period of two years would be desireable in order to evaluate the effect of certain agricultural practices with respect to climatic conditions. One relates to the disposal of animal manures upon frozen versus unfrozen ground.

In the usual case, time limitations or a lack of funds dictate that a relatively short survey of two or three months duration be conducted. If time is not a factor, the engineer must decide whether the greatest return for a given effort will result from a short intensive survey or from a longer term less intensive survey. A good knowledge of the local situation and previous experience aid greatly in making the proper choice.

EVALUATION OF DATA

The day finally arrives when all the flow and chemical data must be translated into terms related to the nutrient problem. At this time the irrelevant data which the engineer may have allowed to be collected at the expense of time and money will be relegated to the waste basket and the focus will be upon the prime nutrients--nitrogen and phosphorus. Because it is known that all inorganic forms of these elements are completely available for the support of phytoplankton and other plant

growths and that organic forms are never completely available, even after extensive biological degradation, it is customary to report survey results in terms of amounts of inorganic and organic forms of each of the elements separately. A highly satisfactory method is by means of bar charts which indicate relative amounts from the various sources. These are readily understood by laymen without technical training, and with whom the engineer must often deal.

Once the data have been resolved into pounds or tons of nutrients originating from the various sources, the engineer has the responsibility of evaluating the data prior to making his recommendations. This may be a very difficult task in some instances and one which will tax the imagination and knowledge of the engineer.

The writer would like to illustrate the evaluation of data by citing two cases from his own experiences, one where the decision was relatively easy and one where the decision was somewhat difficult. These relate to the situation in Lake Waubesa at Madison, Wisconsin, as of 1944, and the other to the situation in Lake Winnisquam at Laconia, New Hampshire, as of 1960. The pertinent data are given in Table 1.

A study of the data will show that Lake Waubesa received 75 percent of its inorganic nitrogen and 87 percent of its inorganic phosphorus from waste waters, which, in this case, was the biologically treated effluent from the Madison Metropolitan Sewerage District treatment plant. In addition, the treated waste waters contributed 34 and 30 percent, respectively, of the organic nitrogen and phosphorus. This information alone was sufficient evidence to indict the waste waters as the major source of the nutrient problem in Lake Waubesa. Another supporting factor was that the main tributary river, the Yahora, was expected to carry less and less nutrients into Lake Waubesa as waste water discharges were eliminated upstream in Lake Monona.

The study of Lake Winnisquam showed that 41 percent of the inorganic nitrogen and 68 percent of the inorganic phosphorus were contributed by the settled

TABLE I: Algal Nutrient Contributions to Lakes Waubesa and Winnisquam

	Nitrogen				Phosphorus			
	Inorganic		Organic		Inorganic		Organic	
	Lb/Yr x 10^3	%	LB/Yr x 10^3	%	Lb/Yr x 10^3	%	Lb/Yr x 10^3	%
Waubesa								
Rivers & Streams	225	25	192	66	16	13	35	70
Waste Waters	688	75	100	34	113	87	15	30
Winnisquam								
Rivers & Streams	121	59	227	80	14	32	40	52
Waste Waters	83	41	57	20	30	68	8	8

waste waters of the Laconia State School and City of Laconia primary treatment plants. They contributed only 20 percent of the organic nitrogen and 8 percent of the organic phosphorus. In only one instance, the case of inorganic phosphorus, did the contribution from the waste waters exceed that from natural drainage.

From a casual study of the data on Lake Winnisquam, one might be led to the conclusion that the contributions from waste waters are a minor factor in the nutrient problem there. Engineering judgment, however, dictated otherwise. This judgment was based upon two facts which became major considerations in the evaluation. The first is related to the nature of the rivers and streams flowing into Lake Winnisquam About 94 percent of the flow into the lake comes from Lake Winnipesaukee and it carries with it in excess of 92 percent of all the nutrient materials contributed by natural streams. Since Lake Winnipesaukee, including Paugus and Opechee Bays through which its waters flow, have always been well behaved in terms of freedom from algal blooms, there is no reason to believe that waters derived therefrom will behave differently when they reach Lake Winnisquam. On this basis alone, one can conclude that the problem in Lake Winnisquam is due to nutrients supplied by waste waters. A second factor which adds to the argument is related to inorganic phosphorus, of which 68 percent originated in waste waters. Studies by Sawyer and Ferullo[14], Shapiro and Ribeiro[13], and others have shown that phosphorus can support blooms of nitrogen-fixing blue-green algae such as those which have caused trouble in Lake Winnisquam.

RECOMMENDATIONS

If the survey results show that the nutrient problem in any given situation is due to sources which can be brought under control by sound engineering practices, the engineer has the responsibility of evaluating them in terms of cost-benefits for the purpose of making recommendations to the client. In general, this would involve methods of waste water treatment and disposal but would not preclude sanitary waste water overflows, storm water, agricultural drainage and even farming practices. Most, or possibly all, enter into

every problem.

With respect to the treatment of disposal of waste waters, the engineer will often be faced with two alternatives: whether to divert them to some other location or whether to provide tertiary treatment for the sole purpose of removing the offending nutrients. The former may be the more economical solution in many cases but is fraught with legal and political implications of a wide variety. The latter can be expensive from the standpoint of both capital and annual operating costs and its effectiveness is largely unproven. The engineer is often in a dilemma when the matter of recommendations confronts him. Political and legal knowledge must supplement engineering and scientific knowledge at this point.

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"APPLICATION OF RESEARCH INFORMATION TO DESIGN AND OPERATION OF INDUSTRIAL WASTE FACILITIES"

BY

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Papers presented at industrial waste conferences fit generally into two categories; research or practical. Very often "research" or "academic" papers deal with laboratory investigations which are not looked upon as realistic problems by design engineers. On the other hand, the "practical" papers often merely recount the design characteristics of a recent project and are not considered very challenging by researchers.

The writers feel, very strongly, that there should be and can be a much closer relation between these two areas. There should be more interest from the academic or research people in investigating areas of significance to the practical engineer, such as problems that are currently of pressing need in the real world. Laboratory research projects can be directed toward obtaining information for the solution of some of these problems. Although such research may not always produce a solution to the problem, it is often possible

to explain why some of the problems exist and to propose directions of pursuit that may help to eliminate them. Similarly, the designer is in a position to rely more on the academic or research people for information that he would not otherwise have, but should utilize for purposes of design.

Perhaps one of the most significant prospects for drawing together these two groups of engineers lies in the concept of the rate limiting step in process design. Biological treatment of industrial wastes is a rate process; the rate at which a waste is oxidized can be expressed in terms of mass of organic matter per mass of organisms per unit time. Hence, the design of a process can and should be based on rate information. The contention of the writer is that if basic factors are considered during design much effort could be saved on readjustment and alterations of plants after initial operation.

Some of the operational difficulties which have come to light in recent years in industrial waste problems have been the result of practices which were completely acceptable as "safety factors" in municipal waste treatment. Cases exist where, due to excessive residence time under aeration, organisms become too starved. In this condition organisms do not settle well, resulting in operational difficulties. There are also cases where too large a mass of organisms is used in the reactor, thus placing an overload on the oxygen system, without increasing organic removal. In addition, odours can result from such practices. Both of these situations involve process "underloading" but with entirely opposite manifestations.

Process design procedures should recognize the reactions occurring during treatment. Designs should be governed by the slowest step in the reaction sequence. This concept is analogous to the weakest link in a chain where the strength of the entire chain is determined by the strength of the weakest link. Process design should be governed by the slowest of all of the steps necessary to reduce organic content to the specified effluent quality.

This rate-limiting concept may be illustrated by considering the role of soluble matter in industrial waste treatment. In particular, we are interested in the fraction of organic matter in the waste which is soluble as opposed to that which is colloidal or suspended. Biological organisms can use only soluble material; organic matter that is not dissolved cannot be directly utilized by microorganisms. Hence, if there is suspended or colloidal matter in a waste, it must first be solubilized by enzymes before being used by organisms. Since enzyme hydrolysis is a very slow process and consumption of the resulting solubles by organisms is relatively fast, the overall rate of breakdown of such a waste would proceed only as fast as the enzyme hydrolysis step. Therefore, for a situation in which this is the case, there must be sufficient residence time of the waste in the reactor for the enzymes to fulfill their function. However, an excess of microorganisms is not desirable because the food becomes available very slowly. If a waste contains only soluble organics, the reaction rate will be considerably faster. In both cases, however, the process should be designed for a contact time based on the unit rate of degradation of the organic matter and the selected concentration of organisms.

The following example is given to illustrate the application of this principle. In the case of insoluble matter, flowsheets such as "contact stabilization", "bio-sorption", etc., are designed to separate, from the process stream, the suspended and colloidal matter along with organisms after a short "contact" time. The resulting concentrated mass is aerated separately allowing the time required for enzyme hydrolysis. For this reaction a smaller tank may be used because the volume of material is small in relation to the process waste stream. Removal of the colloidal and suspended matter from the main waste stream during the contact time is an entrapment process (i.e., the organic matter in colloidal or suspended form is physically attached to or entrapped in the floc). This process is purely a physical one which occurs quite rapidly. Hence only a short contact time is needed, in the "contact" basin, between the process waste stream and the biological mass. The rate limiting step for the design of the

contact basin for the main stream of waste is thus the rate of entrapment. Similarly, for the stabilization unit the rate limiting step is hydrolysis by enzymes. Hence, design of this unit should be based on the time required for the insoluble material to be solubilized.

It is informative to look at this rate-limiting concept with respect to system selection. Clearly, in a situation where organics are primarily colloidal in nature, the "contact stabilization" type of system is appropriate. However, contact stabilization is not applicable to wastes containing appreciable amounts of soluble organics. Soluble matter is not trapped in the floc in a contact unit. In addition, the contact time usually provided is too short for biological oxidation of soluble organics. For soluble organic wastes, there is also no advantage to the stabilization unit other than as a storage reservoir for organisms.

A good example of the misapplication of the so-called contact stabilization system is a design that has been widely publicized in the last few years by the equipment manufacturer, the process consultant, and the industry. In actual fact, the final design was not "contact stabilization" as witnessed by the fact that the contactor unit had to be enlarged many times before the system worked. On close analysis, it can be seen that the situation which was dealt with was a primarily soluble waste. Hence, there was no reason for contact stabilization. The plant functioned, however, as long as the main reactor provided sufficient reaction time for the solubles, even though the regeneration unit was redundant.

Another good example of the misapplication of fundamentals is the panacea implications of "lagoons", or "stabilization ponds". Lagoons have been a good answer to problems of treatment of municipal sewage in many cases and with good reason. Municipal wastes contain primarily colloidal and suspended organic material. There is usually very little soluble organic content. In particular, after wastes have been retained

for long periods in pumping stations and in trunk sewers leading to a lagoon, the organisms present in the waste may have removed all of the soluble organic matter. Thus, municipal waste entering a lagoon contains primarily suspended and colloidal matter. This material settles under quiescent conditions in the pond and slow anaerobic breakdown of settled solids occurs under the overall protection of a buffer zone of oxygen near the surface. Hence, treatment of a municipal waste may be effectively accomplished and odours should not result.

However, when lagoons are applied to industrial wastes containing primarily soluble material, a different situation results. Soluble matter does not settle, of course. Soluble matter undergoes a rapid rate of breakdown; therefore, a shortage of oxygen may occur near the surface of the pond. Odours are often produced from the subsequent anaerobic reduction of sulphurous compounds. Virtually every case of lagoons with odour problems that has come to our attention supports this contention. These lagoons have been handling industrial wastes which are primarily soluble, such as dairy wastes, starch wastes, sugar beet wastes, and petrochemicals.

The foregoing illustrations have been intended to show how decisions in biological wastes process selection may be aided by applying research information and how operational difficulties might be avoided.

Another area for cooperative efforts is in the interpretation of laboratory information for design. This area includes measurement, and the parameters which we use for measuring the effectiveness of treatment. For many years now, it has been common in the field of waste treatment to refer to the strength of organic matter and the efficiency of removal of organic matter in a treatment process in terms of five-day BOD.

A discussion of the application of laboratory techniques to design would not be complete without clarification or amplification of the terminology "five-day BOD".

For many years five-day BOD (BOD5) has been the sole yardstick for strength of wastes with respect to pollution regulations, surcharge limits, and efficiency of waste treatment processes. The term has thus come to be regarded as a definite measure just as temperature is measured in degrees Fahrenheit or Centigrade, or hydraulic flow measurement in terms of cubic feet per second. BOD5 is thought of as a measure of organic matter that can be oxidized by organisms during biological degradation. Hence, process efficiency is represented by relating BOD5 concentration of a waste entering a plant to BOD_5 of the waste leaving the plant.

However, it should be noted that BOD_5, as measured, is not a conserved quantity as is mass or energy. This means that a balance on BOD_5 cannot be obtained in the same way as for mass of a compound or mass per unit volume. Mass and energy can, of course, neither be created nor destroyed and there must be a complete balance on any process if mass or energy are used as parameters. However, BOD_5 used as a measurement is merely the oxygen consumption measured over a given period of time while a reaction occurs with organisms. Since the extent of reaction and time of measurement vary, BOD_5 does not represent a conserved quantity and cannot be used as a measuring parameter in order to obtain a balance on any given process or biological system. We cannot, therefore, expect to get any meaningful relation between BOD_5 in the influent and BOD_5 in the effluent.

One of the chief weaknesses of the BOD_5 test is the discrepancy of the time scale. For instance we do not know when the zero time should be set. Normally, we arbitrarily assume a zero time from the moment that the waste sample is put into BOD bottles and incubation commenced. However, the organisms in the waste may have been reacting with the waste for a long period of time prior to preparation of the samples in the laboratory. This is quite true, for instance, in the case of samples collected in the field and brought to a laboratory without preservation.

Of interest is a discussion of BOD in terms of soluble content of the waste. If a waste containing

only soluble organics is placed with organisms in BOD bottle and observed with time, the initial curve of oxygen uptake (in the first day or so) resembles a bacterial growth curve. At the upper, relatively flat, portion of the curve all of the oxidizable organic matter which is soluble has been consumed by the organisms. However, if we continue to observe the oxygen uptake over a longer period of time, up to a period of five days, we will see that the curve continues to rise steadily, showing that oxygen is being consumed, even though all of the organics have already oxidized.

On the other hand, if we select a waste that contains considerable insoluble material, we can similarly observe that any soluble material present is consumed rapidly. The initially rapid oxygen uptake with time levels off and then proceeds more slowly in a manner similar to the completely soluble case just discussed. It may be hypothesized that some of the insoluble material is being broken down by enzymes and becomes available as food for the organisms.

A significant amount of information can be obtained by following the oxygen demand curve with time over the entire period as opposed to merely measuring the oxygen demand at the fifth day. However, it is often said that tracking a BOD curve for its entire time is merely of interest to research or laboratory engineers. The following example illustrates how the information taken from only a five-day BOD value can be misapplied in a design sense to cause considerable woe in the operation of a waste treatment process.

While the strength of a waste is usually assumed to be represented by the BOD, in actual fact the strength is defined by the plateau value of the BOD curve, which is often as much as 40% less than the five-day value. If the five-day value is used as a basis for the design of the oxygenation system, then a common operating difficulty may result. Design has been based on a higher concentration of food than actually exists. The resultant high concentration of organisms may produce a problem of poor settleability due to the shortage of food. This operational difficulty often reflects upon the equipment manufacturers who are accused of providing poor oxygen transfer. To be noted also

is that very often this situation occurs in field practice when a plant is quite new and has not achieved its full design loading. Thus, there may be an even more extreme shortage of food for the amount of organisms used.

In summary, there are definite weaknesses and inconsistencies in the use of BOD_5 in that this value does not provide an obsolute measure of strength as many have come to believe over the years. However, it is important for design engineers to realize that information obtained from the BOD test can be valuable both for design and for operation. Perhaps this is not the very best information which we are able to obtain on a scientific basis, but certainly it is much more accurate and more meaningful than a mere measurement of five-day oxygen uptake value, or "five-day BOD".

In many ways, the best measurement of the degradable portion of an organic waste is the change in organic content measured either by COD or by total carbon, using a mass culture or an activated sludge of approximately equivalent concentration to that used in a treatment process. In experience with actual wastes, the test period may range from as little as two hours to as high as eight or ten hours. The T_bOD test gives realistic information on the degradability or the pollutional strength of wastes, as well as the quality of the effluent from a treatment plant. It can be contended that this measurement is the only definitive measurement of efficiency of a treatment process. The test can readily be run in a plant laboratory with very little equipment and is a valuable tool for plant operational control. It is also invaluable for obtaining information on degradability of a waste for design purposes.

It is appropriate to comment at this time that there is really no longer such a thing as a municipal waste. We should stop assuming that we know the value of BOD or suspended solids or of other characteristics of any waste because we classify it as a "municipal waste". Most of the larger cities now contain many industries that choose to have their waste treated by the city. Hence, the organic content of the "municipal"

waste is grossly changed, as is the diurnal flow variation. Many of the industries discharging organic pollutants work 24 hours per day and therefore there is stronger waste over the night hours than there normally is from a solely domestic situation. Because the techniques are available for measuring the acutal organic content of a waste and using this for design information, we should use these data instead of assuming a "municipal sewage" as in the past.

CONCLUSION

In summary, this paper tries to point out some of the areas available for close cooperation between research and design engineers. It is our contention that there are many more such areas for a blending of time and talents in order to bring about a greater understanding and more effective solutions to our common problems. Design and operation of biological waste treatment systems, based on meaningful fundamental studies, can lead to significant increases in treatment results.

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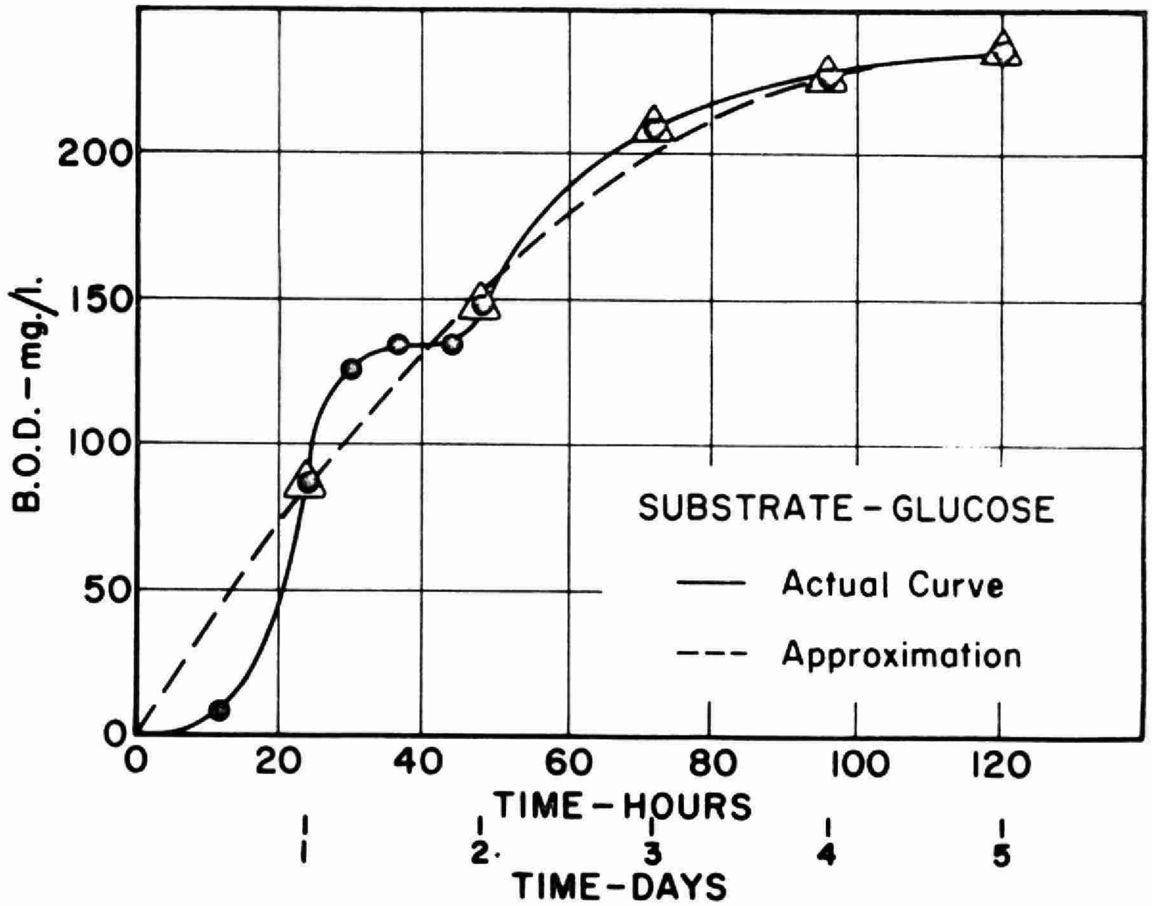

FIG. 1 - TYPICAL B.O.D. CURVE SHOWING FIRST ORDER APPROXIMATION

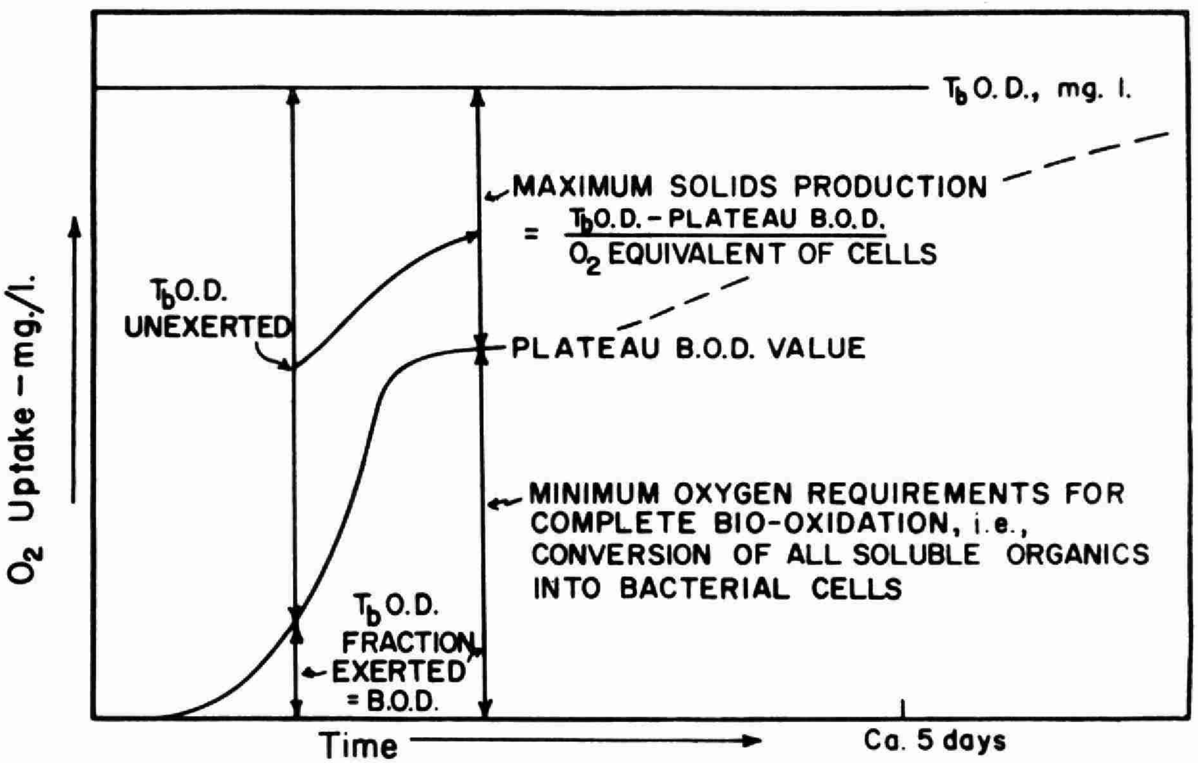

FIGURE 2 - THE TOTAL BIOLOGICAL OXYGEN DEMAND CONCEPT (T_b O.D.) FOR THE B.O.D. BOTTLE TEST

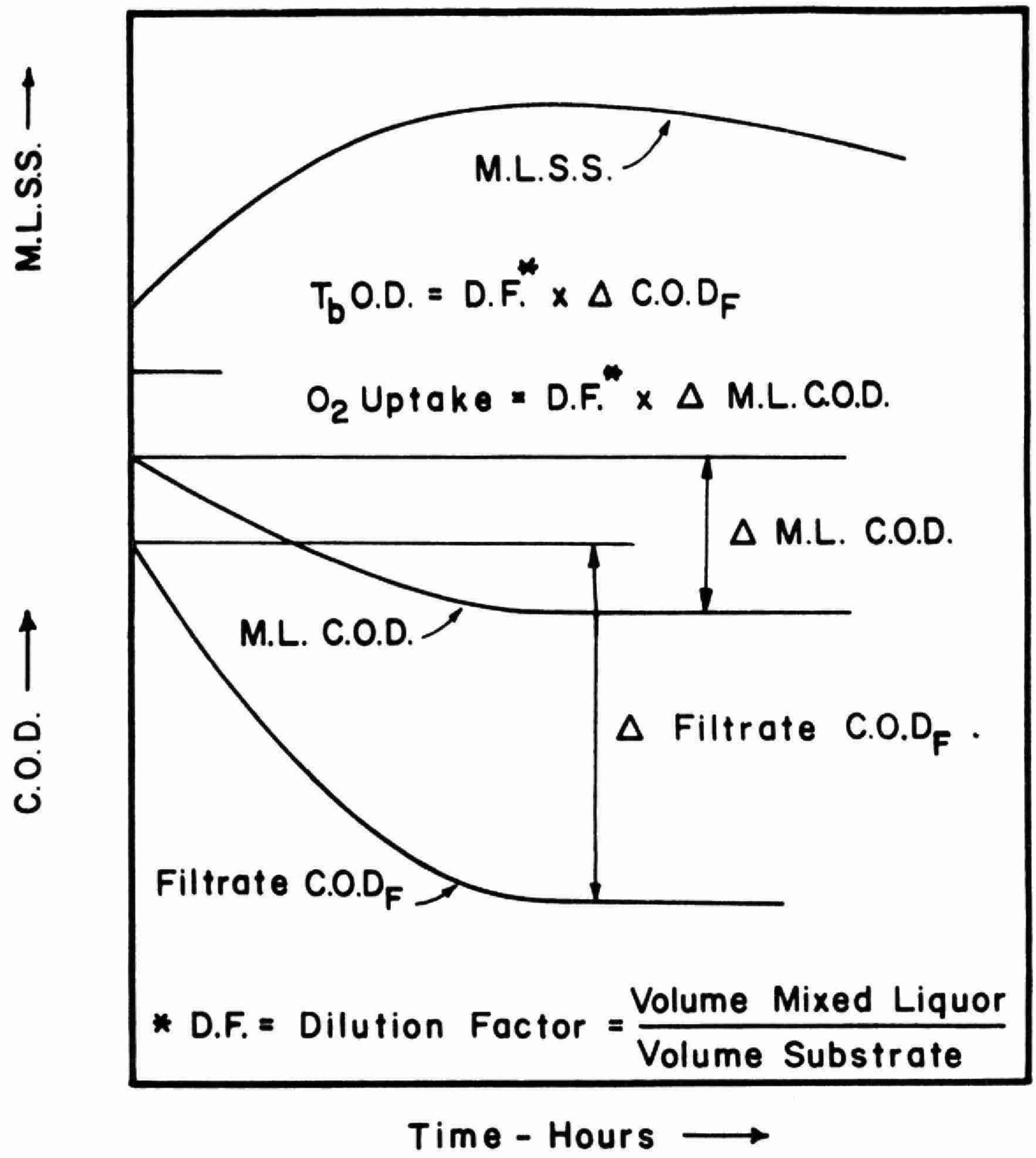

FIGURE 3 - DEFINITION GRAPH FOR MASS CULTURE T_bO.D. PROCEDURE

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"RECENT DEVELOPMENTS IN FLOTATION FOR INDUSTRIAL WASTE TREATMENT"

BY

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The federal push for a better water clarification program has brought about much needed activity within the waste water treatment field. This activity includes water reclamation programs where waste from industry is treated and used again, and where partial treatment is used before the plant waste is discharged into city sewers. Using water for the second or third time in many plants might well justify a good treatment process, but in most cases this treatment has placed an extra financial burden on the industry. Increased pollution problems have forced the regulatory agencies to push for better treatment, thus industry is looking for ways to accomplish this.

The purpose of this paper is to point out the advantages of the improved flotation process and to suggest possible applications. This process is not a cure-all by any means, but if it is properly applied and operated, many industrial waste treatment problems can be corrected by using it.

Dissolved air flotation can be defined as a process whereby air is dissolved into water under pressure, then released back to atmospheric pressure in a liquid form, thus forming very small bubbles which attach themselves to solids particles and lift them to the surface of the liquid.

This process has been used for reclamation of raw products in many industries for several years. The industries such as paper, oil, soap, and possibly others probably have found flotation to be beneficial to them, but in general the process has not been popular until recently. New improvements to the process and a desire by industry to solve pollution problems have created a much greater demand for the process.

This increased demand in the industrial field, plus a desire by Sanitary Engineering Consultants to find an acceptable process for concentrating waste activated sludge, has stimulated research work within the companies supplying equipment for the waste water treatment field. The writer cannot speak for other companies, but many hours of research were required by our company to develop a flotation process that would meet these demands

OUR RESEARCH APPROACH:

Our research began by reviewing previous work and studying existing installations. We found that some of the older processes did the job which they were designed for, but many of them were abandoned because they did not function properly. These units operated by pressurizing most or all of the flow being fed to the process and then releasing it into a tank. We also found that nothing

was being done to agglomerate the very fine particles within the unit.

We have found that best results can be obtained by pressurizing a portion of the clear effluent or auxiliary recycle water and releasing it through a pressure reducing orifice into the feed flow to the unit. After extensive research and testing, we were able to establish a flotation process that consists of the following equipment.

> A rectangular tank, a cylindrical pressurization tank, a recycle pump, a reaeration pump, an air supply, and a surface sludge collector.

The waste feed enters the bottom of the tank at one end, and is mixed with the pressurized air-water mixture as it is released through a pressure reducing orifice. Flotation aids can be added to the feed just before it enters the flotation unit or they can be added to the air-water mixture after the mixture passes the pressure reducing orifice. After the feed, water and air mixture, and the flotation aids are combined, small air bubbles are formed and attach themselves to the solid particles and rise to the surface. This allows clear water to flow out the opposite end of the tank where a portion of it is picked up by a recycle pump and discharged along with air into the pressurization tank. This flow is also recycled again within the pressurization tank. This is done through eductors to produce a better air-water mixture. Pressure in this tank is maintained from 65 to 70 psi (Figure 1 and 2).

Our research has shown the following necessary requirements for consistent efficiency in flotation operation:

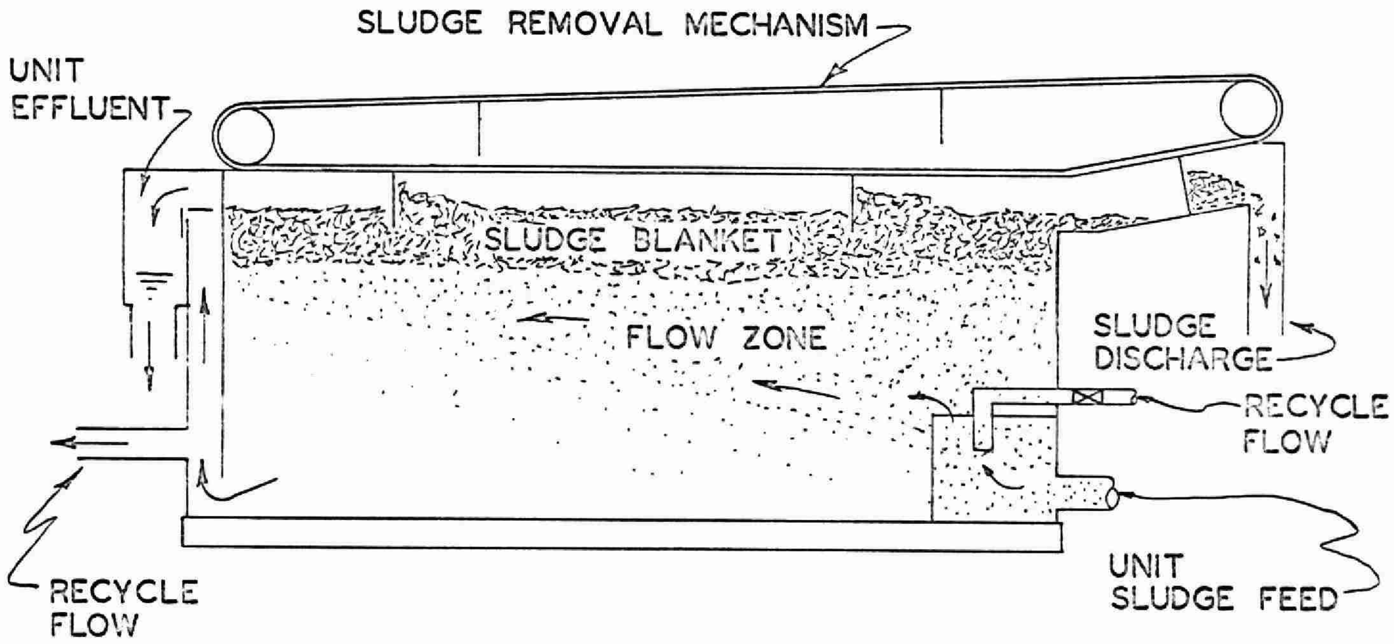

FIG. I INTERNAL FLOW DIAGRAM

H-R TYPE FLOTATION UNIT

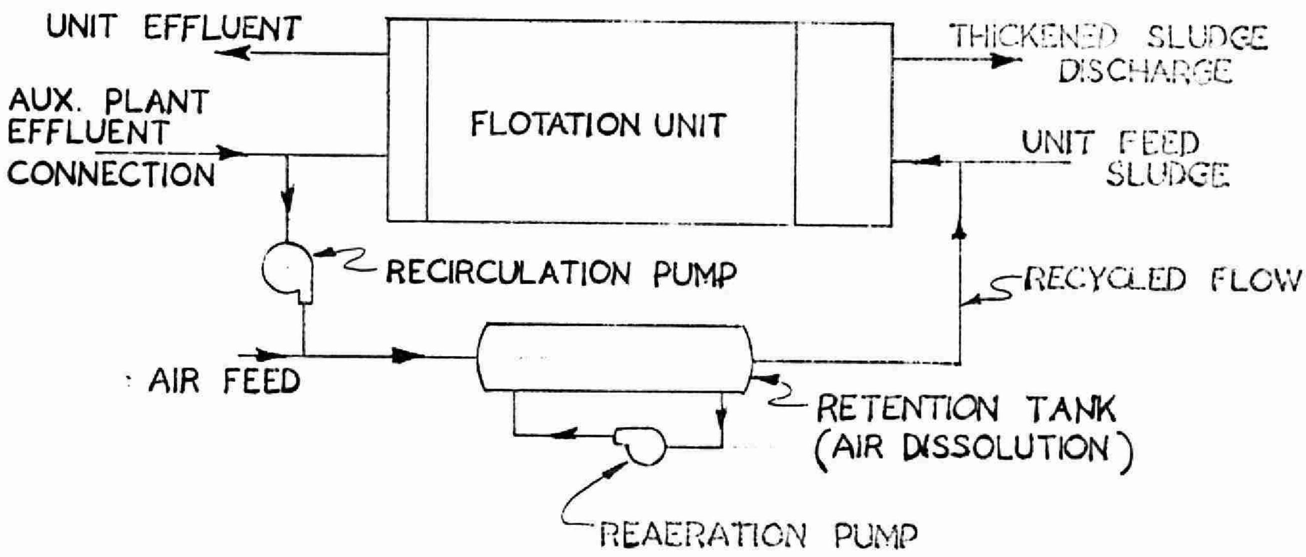

FIG. 2 SCHEMATIC FLOW DIAGRAM

H-R TYPE FLOTATION UNIT

A. AIR TO SOLIDS RATIO

This is a ratio expressed as pounds of air to pounds of solids. It is also referred to as pounds of air dissolved into water, rather than air applied to the unit. There are probably many opinions as to what this ratio should be, but we feel that a ratio of 0.02 pounds of air per pound of solids should be used. There are times when certain waste can be floated with less air, but the 0.02 figure is a good safe margin for design.

Some of the factors which govern the quantity of air that can be dissolved into a given quantity of water are as follows:

1. Pressure (Figure 3)
2. Detention Time
3. Agitation within the Pressurization Tank
4. Quantity of Solids in the Recycle Water.

B. PARTICLE AGGLOMERATION

The very fine particles, even down in the colloid range, in a waste stream must be coagulated, thus forming particles larger than the air bubbles if consistent removal of these particles is expected. These particles are also more irregular after coagulation and their electrophoretic movement is changed to prevent them from repelling air bubbles. This agglomeration may be brought about by bacteriological, chemical, or electro-dialysis action. Activated sludge particles can normally be agglomerated better with the use of a high molecular weight cationic polyelectrolyte. In treating industrial waste (especially those with large quantities of emulsified grease or oil), alum, lime, and possibly an anionic polyelectrolyte should be used if good consistent removal of solids is required. Several electo-chemical processes are now under study. Some of these, especially electro-dialysis, show promise in coagulating solids for flotation operation in both the sanitary and industrial waste treatment fields.

C. HYDRAULIC LOADINGS

We feel that the hydraulic loading in flow to the unit should not exceed two gallons per sq. ft. per

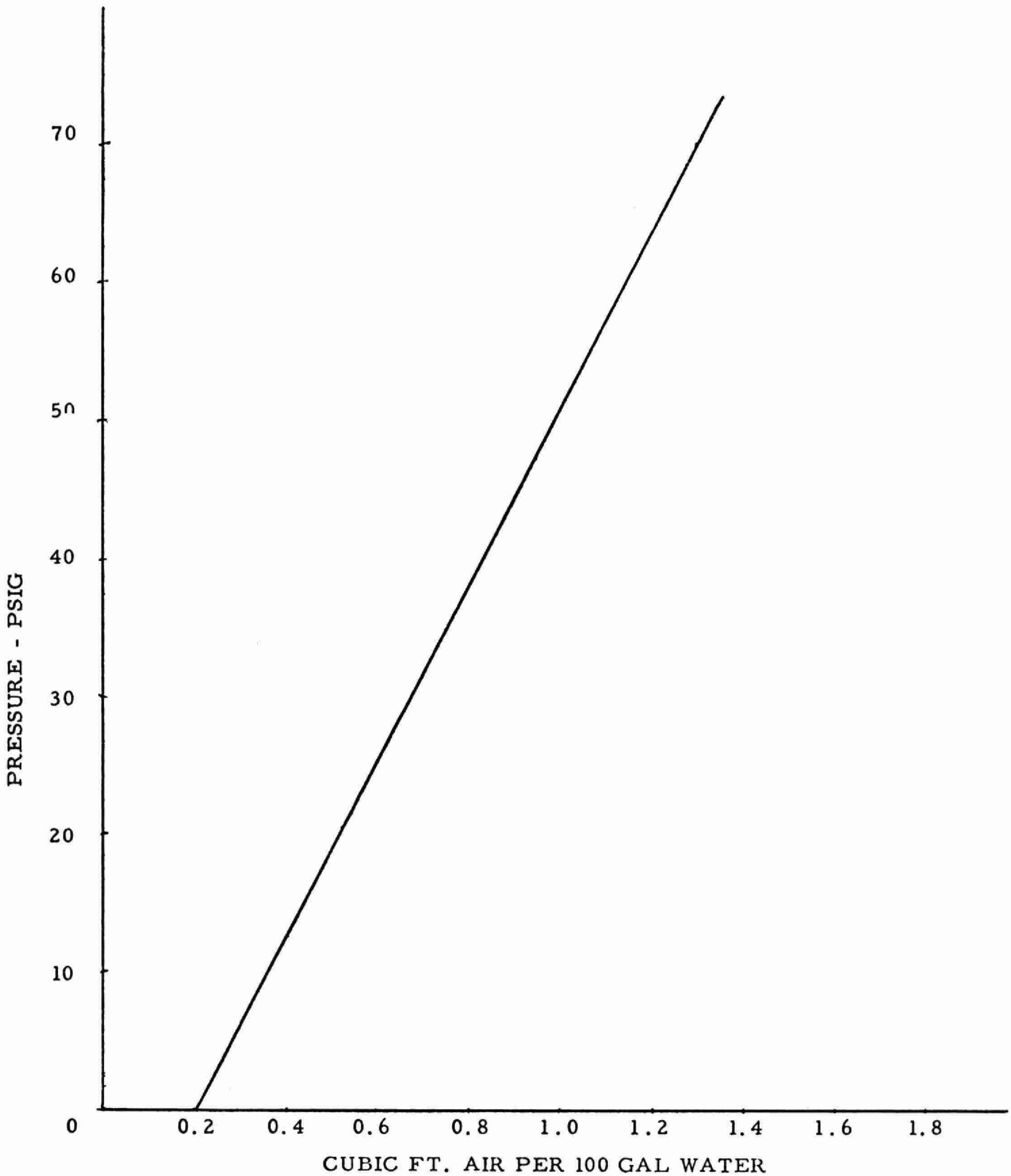

Figure 3 - Solubility of Air in Water

minute. However, in many cases the flow will not reach this quantity as the flow to the unit depends upon the quantity of solids in the flow. As has already been stated, the operation of the flotation unit is an air to solids ratio.

As an example, a feed flow of 400 GPM with 200 mg/1 of suspended solids, could probably be handled in a 200 sq. ft. flotation unit, but if the solids in the flow increased to 8,000 mg/1 the flow would have to be decreased to 100 GPM.

This flow to solids combination can be determined very easily by making a simple jar test. A sample of the air-water, solids, and flotation aid mixture is drawn out of a simple cock installed on the flotation unit. If solids rise to the top of a quart jar forming approximately a 3/4 inch layer in 12 seconds the unit is working satisfactorily. More rise time than this with a thicker layer usually indicates an overload of solids.

We have found the solids loading to the unit to vary from 1.5 to 4 pounds per square foot per hour depending on the degree of solids agglomeration. If solids are agglomerated to large stable particles, then effluent from the unit will be practically clear even with high solids loadings, and the unit will produce a more concentrated float or sludge.

APPLICATION OF FLOTATION UNITS

Our experience has shown the flotation process to be applicable to the following needs:

A. To Thicken Waste Activated Sludge:

Many of the activated sludge processes today are producing waste sludge that will not concentrate by gravity thickening, and engineers are turning to the flotation process as a means of concentrating this sludge.

B. To Treat Industrial Waste:

As has already been mentioned industry is looking for treatment processes that will help them

comply with federal regulations regarding stream pollution control. The improved flotation process can be successfully used for partial or complete treatment of many industrial wastes. Degree of treatment depends upon the customer's desire and his willingness to pay for proper operation.

C. As a Reclamation Process:

When the improved flotation process is used for a reclamation process such as grease, oil or paper pulp removal, then effluent quality is not normally stressed. This effluent is usually discharged into another treatment process. The float from the unit is reclaimed to be used back in the plant process or sold as a by-product. In this case auxiliary recycle water should be used.

SIZING AND DESIGN OF UNITS

Sizing of the units has already been discussed, but a discussion of sizing for specific application is in order. This is discussed as follows:

A. Thickening Waste Activated Sludge:

For this purpose the units are designed with enough recycle flow, detention time, and pressure to supply enough dessolved air in liquid to support a loading of 3 to 4 pounds solids per square foot of surface area per hour, but we recommend sizing the units for two pounds per square foot per hour. This loading can be maintained with 95 per cent or greater removal of solids when flotation aids are used. A typical sizing example is:

> Assume a 5 MGD conventional activated sludge plant has 4,000 lbs. waste sludge per day and a flotation unit is to be used 8 hours per day, 5 days per week. Sizing would be as follows:

$$\frac{4000\ (\text{lbs./day}) \times 7(\text{days/week})}{2\ (\text{lbs/sq.ft/hr}) \times 8(\text{hrs/day}) \times 5\ (\text{days/wk})} = \text{350 sq. ft. of flotation area}$$

Sizing of flotation units for thickening sludge should be considered on a solids loading rather than flow to the unit. This is due to the great variance of solids concentration in the waste activated sludge. If solids concentrations in the waste feed fall below 500 mg/l, then the flow to the unit will have to be considered in sizing the unit. If the horizontal flow through the unit becomes greater than the vertical rise rate of the solid particles then poor operation will occur. We recommend a flow rate not to exceed 2 gallons per minute per sq. ft. of surface area. In designing these for thickening sludge they should be designed with a cationic polymer feeder, feeding directly into the influent sludge feed line. Figure 4, the air-water mixture discharge is a typical layout for a sludge thickening process.

B. Treating Industrial Waste:

Sizing of the modified flotation units for treating industrial waste should be made on a flow basis to the unit rather than solids basis. It is unusual to find suspended solids in industrial waste streams exceeding 5,000 mg/l. For this reason the units should be designed for flow. If total dissolved solids are to be converted to suspended solids with the use of chemicals, then solids loadings would have to be considered. In any case, again the flow should not exceed 2 gallons per minute per square foot of surface area.

The units designed for treating industrial waste are usually designed with two small chemical feeders, feeding into a small flocculator with the flow from the flocculator entering the flotation unit. Figure 5 is a typical layout for waste treatment by flotation.

C. For Reclamation Process

Units designed for this purpose are also designed on a flow basis rather than a solids basis. Again the flow rate should not exceed 2 gallons per square foot per minute. They usually do not require chemical feed equipment, but if they do, then the

SCHEMATIC FLOW
FOR
THICKENING ACTIVATED SLUDGE
WITH H-R FLOTATION UNIT

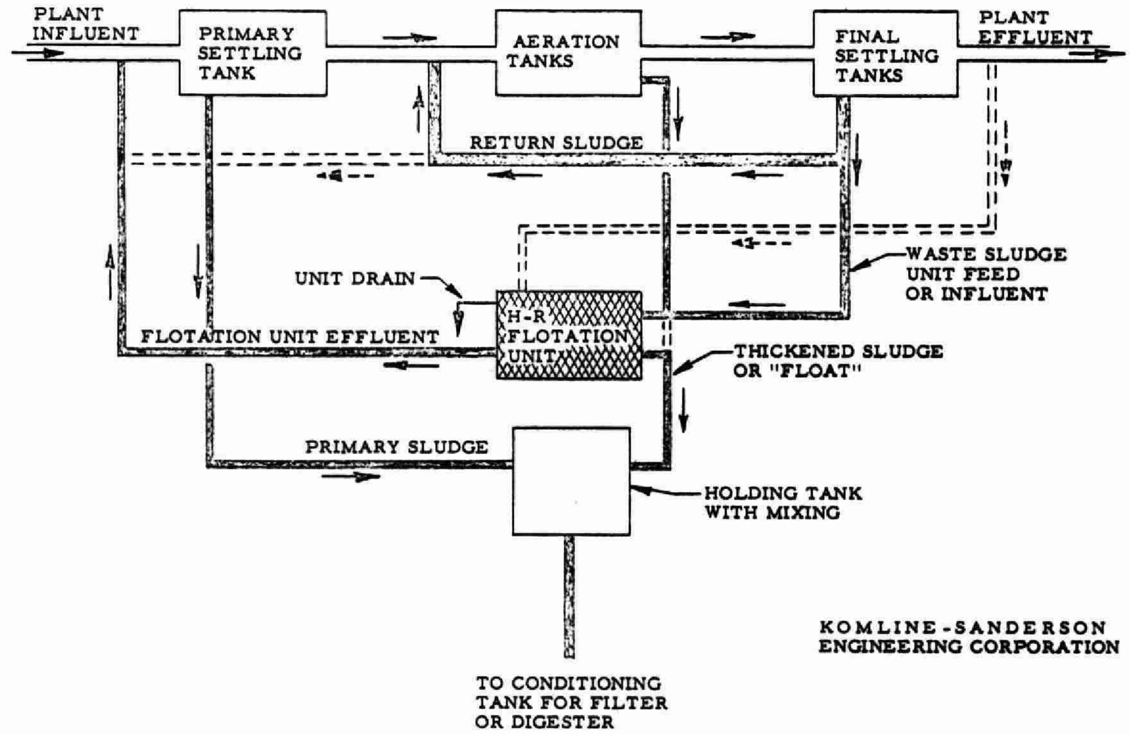

FIGURE 4

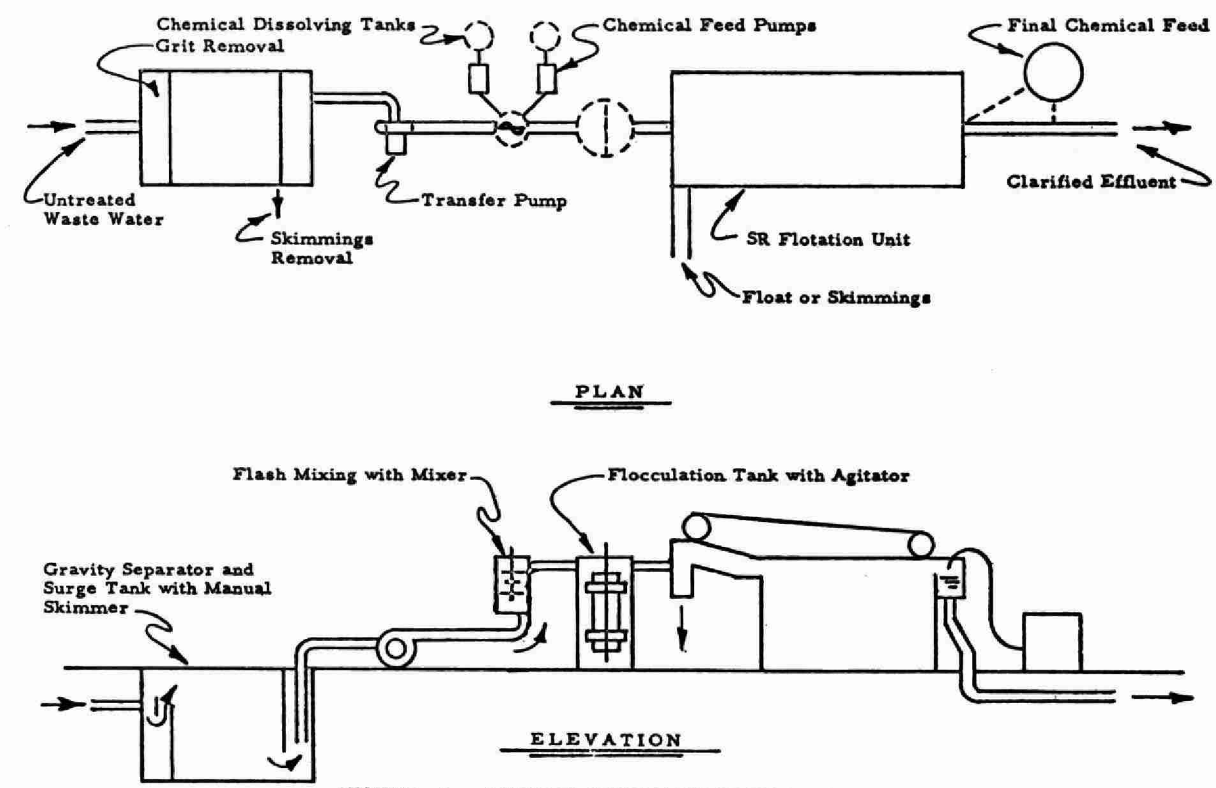

FIGURE 5 TYPICAL SCHEMATIC FLOW DIAGRAM
FOR
GREASE AND OILS REMOVAL FROM WASTE WATERS
WITH SR TYPE FLOTATION UNIT
WITH CHEMICAL PRETREATMENT

same would hold true as for industrial waste treatment.

Each of these applications would require approximately 0.03 scfm of air per square foot of flotation area. The air can be supplied from a small compressor with pressure above 70 psi. This is normal operating pressure in the pressurization tank.

Normal horsepower requirements for these applications are 100 to 200 per ton solids removed (assuming 1,000 to 2,000 mg/l suspended solids in feed) or 250 to 500 per million gallons waste treated.

TESTING AND OPERATION DATA

Data from practically all the test work that we have done and from industries that have rented equipment from us has been compiled for study. It is impossible to show all these data in such a short time, but we have prepared averages from several of these tests. We have refrained from using company names where these tests were performed. We have not asked their permission to use this; therefore, we feel that these names should be withheld. (Table 1)

SUMMARY AND CONCLUSIONS:

After much research and test work we conclude the following:

1. The improved flotation process is an acceptable method for treating industrial waste, reclamation of by-products, and sludge concentration.

2. Suspended solids, BOD, and grease removals will depend upon the pretreatment of waste being fed to the unit. 90 to 99 percent removals can be obtained if optimum pre-treatment is maintained.

3. This is not always an economical process for treating waste, but it is dependable.

4. Pilot plant test work should be performed for specific waste to determine degree of treatment, sizing of units, and cost of operation.

KOMLINE - SANDERSON
ENGINEERING CORPORATION
Peapack, New Jersey

Type Waste	INFLUENT Overflow Rate G.P.M/Ft^2	INFLUENT Sus. Sol. Mg/l	INFLUENT B.O.D. Mg/l	INFLUENT Oil or Grease Mg/l	INFLUENT Total Solids Mg/l	EFFLUENT Sus. Sol. Mg/l	EFFLUENT B.O.D. Mg/l	EFFLUENT Oil or Grease Mg/l	EFFLUENT Total Solids Mg/l	PERCENT REMOVAL Sus. Sol.	PERCENT REMOVAL B.O.D.	PERCENT REMOVAL Grease	PERCENT REMOVAL Total Solids	Flotation Aids
Soybean Processing	1.33	1656	3000	-----	7775	42	800	-----	5394	98.0	73.0	-----	30.0	$FeCl_3$ Lime A-21
Potato Processing	1.50	2600	2760	-----	5130	60	260	-----	1650	97.8	90.0	-----	32.3	Alum Lime A-21
Tomato Processing	1.73	172	276	-----	900	59	168	-----	630	89.5	39.1	-----	34.0	Alum C-3
Beef Processing	1.86	5050	1969	-----	-----	10.5	81	-----	-----	99.7	94.6	-----	-----	Alum Lime A-21
"	1.6	970	1540	1706	-----	97	277	513	-----	90.0	82.0	70.0	-----	Alum Lime A-21
Chicken Processing	1.5	1690	1075	331	-----	275	86	74	-----	84.0	92.0	80.0	-----	Alum Lime A-21
"	1.7	357	630	-----	-----	91	58	-----	-----	74.5	90.8	-----	-----	Alum Lime A-21
Cosmetics & Toiletries	1.5	15,000	24,500	5405	27,460	1800	5880	485	6000	88.0	76.0	91.0	75.0	-----
Laundry Waste	1.0	3469	-----	3014	-----	281	----	475	-----	92.3	----	70.5	-----	Alum Lime A-21
Pork Skin Tanning Process	1.3	7792	-----	20,590	-----	1310	-----	1275	-----	83.1	----	95.0	-----	Alum or C-31

TABLE I - TEST RESULTS OF FLOTATION TREATMENT OF INDUSTRIAL WASTE WATERS

"TREATMENT OF INDUSTRIAL WASTES AT MUNICIPAL WATER POLLUTION CONTROL PLANTS"

BY

R. M. GOTTS & K. H. SHIKAZE & R. ABBOTT

DIVISION OF INDUSTRIAL WASTES
ONTARIO WATER RESOURCES COMMISSION

R. M. GOTTS

Treatment of industrial wastes at municipal water pollution control plants is a subject which receives the consideration of most industrialists at one time or another and is of vital concern to persons charged with the design and operation of municipal sewage treatment systems. Naturally, the economics of joint versus individual treatment of industrial wastes is of major importance in deciding which path to follow.

Since most ventures into joint treatment result in both capital and operating cost savings to the industry, it is not surprising that it is a method of disposing of industrial wastes which has been widely adopted. Obviously, maximum economy should be achieved when wastes from a number of sources can be effectively treated at one treatment plant rather than at individual plants.

Besides the economic factors, legal and engineering aspects of joint treatment must also be considered by both the industry and the municipality.

In the remainder of this paper, these considerations will be discussed as they relate to the industry and municipality's interests. First, however, I would like to present a few statistics on experience in the United States and Ontario to illustrate the widespread acceptance of joint treatment programs.

Some Statistics on Joint Treatment

It is difficult, without the benefit of a comprehensive industrial waste survey, to assess, with any great accuracy, the contribution of industrial waste loadings and their effects at the municipal treatment plant. However, a survey was conducted in the United States by an ORSANCO committee, in 1956, to gather information on the industrial contribution of flow, BOD and suspended solids at municipal plants which were known to be handling combined wastes. The results of this survey were reported by C. H. Allen and others in the Sewage and Industrial Wastes Journal.[1] Questionaires were sent to 192 plants of varying sizes and out of the 100 replies that were received, it was indicated that 63 of the plants were equipped with secondary facilities. The results were as follows:

Median industrial flow	- 25.5 %
Plants with greater than 50% industrial flow	- 16.0 %
Median industrial BOD	- 36.25 %
Plants with greater than 50% industrial BOD	- 35.5 %
Median industrial Suspended Solids	- 32.5 %
Plants with greater than 50% industrial SS	- 25.5 %

A further survey indicated that larger municipalities averaged greater than 50 percent flow from the industries.[2] It is interesting to note that the survey showed that plants experiencing some problems, due to industrial wastes, operated at the same efficiency as those plants without industrial problems.

Available data from a few Ontario plants gave the following information:

Median industrial waste flow	- 30%
Median industrial BOD	- 77%
Median industrial SS	- 52%

These figures are based on only 8 plants, a much smaller sampling than in the U.S. survey. However, the data are more recent and do reflect the increase in industrial expansion over the past decade. It can be seen that the volume contribution of industrial wastes is fairly consistent, but the percentage of industrial BOD and suspended solids is about doubled. A repeat of the U.S. survey would, no doubt, also reflect some increase in the industrial contribution.

The Ontario examples are not meant to reflect overall experience in the Province as they are merely indicative of plants for which data was readily available in OWRC files. In fact, they are likely to represent more heavily industrialized areas and provincial averages may be lower on all counts.

Considerations by Municipality

Aspects to be considered by the municipality are likely to include protection of sewers and treatment processes, policing or by-law enforcement, charges, design effects, and provincial financing, although not necessarily in that order. Many of these factors have been discussed in detail in past Ontario Conferences in papers presented by E. G. Hachborn, D. P. Scott, G. T. G. Scott, C. V. Williams, and N. S. Bubbis.

Protection, design and effects primarily involve engineering, whereas the others are more concerned with legal and economic factors.

(A) Protection of Sewers and Treatment Processes:

Needless to say, there would be little gained by accepting industrial wastes into the municipal sewerage system if they were to cause damage to the system or interfere with treatment processes.

Of primary importance is the safety of personnel who must work on the sewers or operate the treatment plant. The principal dangers to workers involve the discharge of flammable or explosive wastes or wastes containing toxic substances, especially those which could appear in the gaseous phase. Thus, waste components capable of causing such problems must be controlled to limits well below levels

capable of creating these hazards.

Secondly, damage to sewers must be avoided. Problems can be caused in the sewers by hydraulic overload, settled solids, grease and floating solids, and chemicals. The effects of hydraulic overload are obvious. Settled solids can cause difficulties by obstructing or reducing the flow in sewers or injuring pumps, valves, etc. Grease and floating solids lead to similar problems. Discharge of chemicals can lead to accelerated corrosion by acids and salts, liberation of noxious gases, such as hydrogen sulphide, and other undesirable conditions.

Protection of the treatment works and processes involves many of the considerations discussed above. Hydraulic overload can lead to overloading of pumps and other facilities, decreased retention in treatment units, and increases in treatment chemical requirements. Discharge of excessive quantities of settleable solids can cause the overload of primary treatment sludge removal facilities, which could lead to septic conditions as well as present difficulties for disposal of primary or digested sludge. Most plants are not designed to handle coarse and floating solids, so these should be excluded at the source.

The organic overload of a treatment plant can be caused by the discharge of wastes from industries such as dairies, canneries and packinghouses. If this condition is allowed to develop, the plant will have insufficient purification capacity and other operating problems may occur.

Discharge of chemicals can again lead to corrosion and increased chemical demand. Detergent frothing is another problem that can be encountered through excessive discharge of industrial detergents and cleaners. Biological acitivity at a treatment plant can also be seriously affected by the discharge of chemical wastes. Discharge of acid or alkaline wastes containing toxic components such as cyanide, heavy metals, and high concentrations of phenol can interfere with secondary treatment processes. Discharge of heavy metals may also interfere with anaerobic treatment processes in the digester.

In general, protection of personnel, sewers and appurtenances, and the treatment processes can be maintained if the following waste conditions are adhered to:

1) Homogeneous and uniform flow
2) not highly loaded with suspended solids
3) acidity, alkalinity and chemical composition reasonable
4) toxic materials absent
5) reasonable BOD or organic load
6) reasonable grease, oil and floating solids content

(B) Protective Legislation and Enforcement

In order to protect the municipality from excessive inconvenience in the operation of its sewerage system, it is generally necessary to enact legislation providing for regulation of the controls discussed above.

Such legislation, generally in the form of a by-law, may include an introduction, definition of terms, regulations requiring use of public sewers where available, regulations concerning private sewage and waste disposal where public sewers are not available, regulations and procedures regarding the construction of sewers and connections, regulations relating to quantities and character of waters and wastes admissible to public sewers, special regulations, provision for powers of inspectors, enforcement (penalty) clause, validity clause, signatures and attest.

Each by-law should have a clause which will permit special arrangements between industry and municipality. This would allow enough flexibility for the municipality to enter into agreements with industries not able to full-fill the regulations clauses mentioned above. An example of such an agreement was outlined in the 7th Conference in a paper by G. T. G. Scott. [5] To illustrate the need for this flexibility, consider the case where a regulation states that no waste with a BOD higher than 500 ppm can be discharged to the municipal system. In this municipality you may have an industry with a process waste volume of only a few thousand gallons, but which has a BOD of 1000 ppm caused by dissolved organic material. It would be most

unreasonable to expect this industry to install treatment facilities to meet a limit of 500 ppm when the population equivalent of the waste may be much less than 250 or so.

There is no reason to have a by-law on the books of a municipality unless it is to be enforced. Hence, when the regulations are formulated, provisions should be made for sufficient personnel and money to enforce them. This is the prime weakness of many of the by-laws enacted today.

(C) Charges

In many cases, it will be necessary to charge industry for services provided to avoid imposing an unfair tax burden on the general public. Such charges may be in the form of a fixed rate per year, a surcharge on a volume basis or based on waste strength and characteristics such as BOD and suspended solids and various other factors.

The development of sewer service charges that are equitable to all industries and to the municipality is not an easy task. A search of the literature revealed a number of formulae with widely varying degrees of complexity developed for the application of sewer surcharges. A number of these have been discussed in papers presented at the 7th and 9th Conferences by Williams and Bubbis.[6,7]

In using a formula, care must be taken to avoid one which requires an unreasonably complicated program of sampling and analysis. Generally speaking, the smaller the municipality the simpler the method of surcharging must be. If this precaution is not taken, it may end up costing the municipality more to define and collect sewer-use charges than the charges are worth.

A few examples of surcharge applications are presented below:

1) Volume Surcharge

The practice of applying surcharges on a straight volume basis would appear to be the most popular method of recovering costs for sewage treatment services. In many

small municipalities, it is the only practicable means of recovering costs for sewage treatment services. However, it is also probably the least equitable method with the exception of no charge at all. The use of this method involves the levying of a surcharge on the basis of water consumed or discharged to the sewerage system of such a magnitude as to recover all operating costs. Capital costs are generally recovered through assessment.

2) Volume and Waste Strength Surcharges

There are a number of formulae which have been developed for applying service charges on the basis of waste strength and volume. Most of these are limited to taking into account BOD and suspended solids loadings, although many also consider chemical consuming characteristics such as chlorine demand.

One such formula, based on applying charges for excess load, was developed by Dr. S. R. Wright, University of Texas.[8] For a municipality providing complete treatment, this formula would read as follows:

$$F = \frac{300 + R\,(S - 150) + (BOD - 200)}{300}$$

where: F = factor by which volume rate is multiplied

R = ratio of cost of treatment to total cost of operation of sewerage system

S = suspended solids concentration in waste (ppm)

BOD = 5 day BOD of the waste (ppm)

As an example, if R = 0.6, an industry with a discharge containing 100 ppm suspended solids and a BOD of 3000 ppm would be required to pay 8.3 times the unit volume rate for ordinary domestic sewage.

The use of this formula assumes that a basic surcharge on the basis of volume has already been established. If this were not done and a volume factor was not included it could encourage dilution of wastes to

meet the SS and BOD limits below which no surcharge was levied. The effects of such a practice are obvious.

Others

Several formulae have been noted which take into account one or more of the other factors, tangible or intangible, which may have to be considered in a given municipality. An assessment factor has commonly been employed and references to such formulae are numerous. (6,7,8,9,)

Other factors which may play a role in this matter include:

1) Type of treatment plant - none
   - primary
   - complete

2) Capacity of existing plant

3) Character of wastes - volume
   - peak loads
   - Suspended solids
   - BOD
   - toxicity

4) Local municipal policy towards industry, i.e., precedents, etc.

5) Fixed charges

6) Maintenance

7) Assessment versus benefits

8) Adjustments for beneficial wastes

It will be seen from this extensive list of factors that it is impossible to arrive at one formula for basing charges for industrial waste treatment in public systems which will be applicable to all cases.

Considerations by Municipality

(A) Design of Water Pollution Control Facility

Most operators, whether they be associated with a small or large water pollution control facility, will agree on one significant point. That is, operational problems created by industrial waste discharges cause more headaches than any other single problem. The most common reason is the lack of appreciation of the problem by the parties involved due to either limited knowledge or interest.

The design engineer gives full consideration to the domestic waste loadings and flows and, using the standard guides, the design of a treatment facility to handle domestic wastes has become a fairly routine procedure.

However, special considerations must be taken into account in the design of a water pollution control facility which is expected to handle both domestic and industrial discharges. The type of process equipment required and the particular operational problems associated with the combined wastes must be considered. This is particularly true in the case of the small or medium-sized facility which will receive a high proportion of the industrial wastes from only one or two large industries.

In some instances, the combined industrial-domestic wastes may require a waste treatment facility which would be economically prohibitive. However, in other instances, certain industrial wastes may prove desirable and result in savings in the treatment facility or otherwise enhance the operation of the system.

Generally, it is only through the conducting of a comprehensive industrial waste survey in the municipality that an accurate assessment can be made on the contribution that can be attributable to industrial waste discharges to the municipal system. In some cases, it may be possible to single out a few industries which would be expected to contribute a major portion of the loading and conduct a survey at these industries. In any event, the volume and characteristics of the

industrial discharges in the municipality must be determined and duly considered in the design of the treatment facility.

Once all the necessary information has been compiled on the industrial waste discharges, it may or may not be necessary to conduct laboratory or pilot plant studies to determine the efficiency of a treatment system for the combined wastes. Studies on specific industrial wastes in municipal facilities have been well-documented in the literature and may be sufficient in providing the necessary data for design purposes. However, some industrial wastes, by virtue of their complex nature and by being combined with other wastes, may require some special studies to be conducted. Once industrial wastes enter into the picture the following processes and operations may require careful study in the design of a suitable treatment facility.

1. Grit chambers

2. Screens and Comminutors

3. Primary Settling tanks

4. Aeration facility

    (i) oxygen transfer properties
    (ii) loading characteristic
    (iii) removal (efficiency) characteristics
    (iv) oxygen demand rates
    (v) required retention time

5. Digestion tanks

6. Secondary settling tanks

It is the duty of every design engineer to consider fully the influence of industrial wastes in the final design of the facility.

It should be noted here that the design capacity of the facility should include some reserve capacity, not only for population growth but for industrial growth.

(B) Effects of Industrial Wastes on the Operation of Municipal Treatment Plants

Industrial wastes, by virtue of their variety and complex nature, can not be dealt with in their entirety, so one must consider the specific characteristics of the wastes in determining their effect on treatment plants. Further, since most of the treatment plants in Ontario utilize an aerobic biological process, namely the activated sludge process or some modifications thereof, the effects of specific industrial wastes on the treatment process discussed here will refer to the activated sludge process.

Some wastes, as mentioned previously, should never be discharged to the sewer system. Oils, flammables and those materials which may produce noxious or toxic gases should not be allowed into the sewer system. The effects of this type of waste on the activated sludge system will not be discussed. Further, the effect of specific industrial wastes on the sewage collection system will also be omitted. It is only those processes and operations at the treatment facility with which we are concerned at this time.

1) Volume

The discharge of uncontaminated wastes, such as cooling waters, to the sanitary sewer will adversely affect all the physical and biological processes at the treatment plant, particularly if it is already operating at, or near, design flow. Segregation of these clean waters can lead to successful treatment of industrial wastes at municipal plants which would not otherwise be possible because of excessive volumes.

2) Solids

Excessive concentrations of suspended solids as previously mentioned may create difficulties in the handling of a sludge in primary settling tanks and lead to septic conditions. Larger quantities of sludge may tax the design capacities of the various pieces of sludge handling equipment. Suspended solids containing a low volatile fraction may cause a reduction in gas production in digestors.

(3) BOD

Biochemical oxygen demand is the parameter used most often to determine the load on secondary treatment processes. It is also the basis upon which the aeration facility is designed. Provided sufficient air is supplied and the retention period is adequate, BOD loadings up to and moderately exceeding design should not have any adverse effect on treatment.

However, it should be noted here, that to operate effectively and consistently, the activated sludge process requires a proper balance of nutrients, namely nitrogen and phosphorus.

For example, an industrial waste containing BOD mainly in the form of starches or sugars may upset the nutrient balance at the treatment plant and supplementary addition of nutrients may be required.

For the above case, the deficiency of nutrients may cause bulking problems in the final clarifiers.

(4) Oils and Greases

Oils and greases fall into two main classes; those of animal or vegetable origin which are generally amenable to treatment and those of mineral origin which are not easily decomposed. Excessive quantities of either can cause operating difficulties through clogging of air diffusers or otherwise inhibiting oxygen transfer in secondary treatment units. Digester operations can also be curtailed especially by the presence of mineral oil.

(5) Acid and Alkali Wastes

Apart from the corrosive nature of extreme $_{p}H$ wastes on the sewer system and plant equipment, slugs of wastes whose $_{p}H$ lies outside the range of 5.5 to 9.5 may seriously affect the aerobic biological process which is extremely sensitive to sudden changes in $_{p}H$.

(6) Heavy Metals

Heavy metals generally affect sewage treatment processes because of their toxic effect on the organisms responsible for aerobic and anaerobic processes. The literature contains extensive references on this subject but unfortunately can be confusing to the novice because so many variables enter into the subject of toxicity. In fact, it can appear at times that almost any argument on the degree of toxicity of the various metals and their concentrations can be substantiated by the literature.

To keep the treatment of this subject brief here, the findings of recent studies on the effects of heavy metals as carried out at the Taft Center in Cincinnati, are presented in summarized table form. [10]

EFFECT OF HEAVY METALS ON SEWAGE TREATMENT PROCESSES [10]

	Effect on Aerobic Treatment	Effect on Anaerobic Treatment
Copper	Concentrations up to 1mg/1 do not have detectable effect on treatment. 4-hour slug dose greater than 50 mg/1 had severe effects on unacclimated system.	5 mg/1 in raw sewage had no effect on gas production. Slug doses up to 410 mg/1 did not affect normal digestion.
Chromium	50 mg/1 in sewage feed does not affect BOD removal efficiency. Slug dose of 500 mg/1 affected treatment efficiency for 4 days. Slug dose of 500 mg/1 in actual plant had no effect.	50 mg/1 feed caused reduction in gas production. Slug dose of 500 mg/1 caused digester failure. Slug dose of 500 mg/1 in actual plant had no effect.

	Effect on Aerobic Treatment	Effect on Anaerobic Treatment
Nickel	2.5 - 10 mg/l in sewage feed reduced BOD removal efficiency up to 5%, 200 mg/l slug dose seriously affected treatment efficiency for 2 days. Up to 2.5 mg/l continuous feed does not have any effect on treatment efficiency.	Up to 40 mg/l did not affect sludge digestion.
Zinc	Maximum levels of zinc not having effect on treatment efficiency found to be between 2.5 and 10 mg/l. Slug dose (4-hr) of 160 mg/l	Sludges containing 10 mg/l Zn as $AnSO_4$ had no effect on digestion. Sludges containing 20 mg/l Zn as ZnSO caused rapid failure of digestion process.
Combination of Heavy Metals Copper Chromium Nickel Zinc	Combination of these metals with total concentration of 8.9 mg/l had no effect on treatment efficiency No synergistic action noted. Nitrification almost completely inhibited.	Combined concentration of 8.9 mg/l had no effect on anaerobic digestion.

In general, the ions of other heavy metals, such as cadmium and cobalt, affect the biological processes in much the same manner as those discussed earlier.

(7) Cyanide

Cyanides are among the most toxic of compounds that occur in industrial effluents. Cyanide wastes originate not only from electroplating and metal treating industries, but also in coke and gas manufacture and in

the production of various chemicals, plastics, etc. Often cyanide in waste discharges occurs concurrently with the heavy metals previously discussed.

Ridenour and Greenbank (11) found that increasing concentrations of sodium cyanide from 1 to 40 mg/1 caused temporary reductions in BOD removal and nitrifications but recovery of the pilot plant was rapid. Generally a considerable portion of the cyanide is blown off in the aeration process.

Initial introduction of cyanide to a digester will cause a reduction in gas production, but after acclimitization, the gas production returns to normal.

(8) Colour

Colour usually enters the sewer system as a result of batch dye discharges from textile operations. While colour in itself does not affect the operation of the aerobic biological process, the process does not always readily remove colour and an aesthetically undesirable condition can be created in the effluent and the receiving stream.

(9) Other Constituents in Industrial Discharges

Inert fibrous material such as feathers and rags can affect the proper operation of pumps, valves, bar screens or comminutors. These materials can also create overloading conditions in the digester. Fibrous materials can seriously affect the proper operation of sludge collection devices in primary clarifier units.

Detergents can cause excessive foaming in aeration tanks. Of course, one cannot neglect the more exotic chemicals, especially organic, which can appear in any given waste. One may not so readily find the effects of these materials documented in the literature as new ones are constantly appearing as technological advances are made in industry and demands for newer and better products continue to grow. Therefore, with many such materials one will need to resort to pilot plant studies or trial and error procedures to determine their effects.

CONSIDERATIONS BY INDUSTRY

A. Treatability

The treatability of industrial wastes is of primary concern to the municipality as it has a direct responsibility for the satisfactory operation of its system. It is for this reason that much of the preceding dealt with the topic of treatability automatically when protection, design and effects were discussed. However, industries considering the use of a municipal sewerage system for the treatment of processing wastes have a moral obligation to ensure that the wastes they discharge are amenable to treatment or at least do not have a deleterious effect on the sewerage system or treatment processes.

Naturally, the final decision on whether a waste is amenable to treatment, or not, depends on the evaluation of a number of variables relating to physical, chemical and biological aspects of collection and treatment of the wastes. Most of these variables have been discussed previously and include volume and uniformity of flow, pH, solids content, BOD, toxicity, grease and oil content, nature of treatment processes, treatment plant capacity, etc.

B. Pretreatment Requirements

In considering the foregoing, an intimate knowledge of the pretreatment requirements upon which successful collection and treatment of the wastes depends, will have been obtained. In many cases, certain minimum pretreatment requirements will be dictated by municipal by-laws regulating the characteristics of wastes discharged to public sewers. This will lead to certain obligatory pretreatment operations such as screening, settling, neutralization and equilization.

It is evident that industries having wastewaters containing excessive concentrations of suspended solids, grease or oil, toxic components, etc., must consider pretreatment a condition of acceptance into a municipal sanitary sewerage system. This very essential

part of the pretreatment of industrial wastes, prior to acceptance into municipal water pollution control plants, often produces sludges or oily residues which must be disposed by the industry. This can become an embarrassment in urban areas where suitable disposal sites are not readily available and pressure upon industry by regulatory agencies to "clean-up" pollution accentuates the problem. Potential problems in this regard should, therefore, be noted in considering the disposal of pretreated wastes to a municipal system.

Certain optional pretreatment requirements, such as in-plant controls and process changes to improve efficiency, may be determined by the manner in which a sewer-use surcharge is levied. If, for example, the surcharge is levied on the basis of waste flow, the segregation of clean waters, such as cooling waters, from the waste flow to the municipal system has obvious advantages. If the surcharge is levied on the basis of waste loadings, it becomes desirable to investigate the recoverability and re-use of certain waste constituents with a view to increasing over-all plant efficiency and reducing waste loadings accordingly.

Other optional pretreatment requirement may be predicated by cost considerations where the costs of removing or rendering harmless certain waste constituents at the industry is more attractive than paying a surcharge for removal at the treatment plant. Segregation and pretreatment of strong wastes at the industry for removal of gross quantities of contaminants could fall into this category.

C. Costs of Alternative Treatment

Having determined the technical feasibility of discharging industrial process wastes, pretreated or otherwise, to the municipal system it naturally follows that a close examination of the costs involved should be made, with particular reference to other methods of disposal. The cost and degree of complexity, of necessary pretreatment at the industry, to meet state or provincial regulatory agency pollution control requirements, will be a determining factor in the decision to undertake joint treatment.

The burden remains with the industry to determine the most economically attractive of the two paths which lead to complete treatment. Certainly preliminary engineering reports with cost data will be required in most cases before a decision can be made with any degree of certainty.

D. Control Measures

In considering the discharge of industrial wastes to a municipal system, it must be realized that there are obligations on the part of the industry to ensure the protection of the municipal system from the harmful effects of accidental spills.

Obviously, the best control of spills, etc., is prevention and built-in measures to isolate objectionable wastes from the municipal system. This may involve the installation of process waste monitoring equipment such as pH recorders, or flow and tank level alarm systems.

Reverse Considerations

Up to this point, we have considered only the discharge of industrial wastes to a municipal sewerage system. In a few instances, it may be convenient to consider the reverse, that is, the treatment of municipal sanitary wastes in an industrial wastes treatment plant. Opportunity for such a system could arise in a small "one industry" municipality, particularly if the industrial wastes require conventional treatment and exceed the volume and strength of municipal wastes. Here again, the economic, engineering, and legal aspects would have to be considered.

Examples

To illustrate the acceptance of joint treatment of industrial wastes in Ontario, a table has been prepared and is presented below outlining basic data on the 8 plants previously used for statistical purposes. Study of the table indicates that these plants receive wastes of widely varying composition, flow and loadings and yet, even under conditions

SUMMARY OF MUNICIPALITIES WITH COMBINED TREATMENT IN ONTARIO

	A	B	C	D	E	F	G	H
Design Flow (MIgd)	4.0	0.8	1.8	0.5	13.5	5.0	2.0	1.5
Actual Flow (mIgd)	2.34	0.47	0.78	0.42	8.3	5.6	2.2	1.4
Design BOD Load lb/day	12.000	1,920	5,400	1,000	40,500	12,500	4,400	3,800
Actual BOD Load lb/day	15,800	1,500	3,340	800	37,400	7,800	12,500	5,950
BOD removal %	85.5	98	96	94.5	95.5	91	94.5	81
Design SS Load lb/day	10,800	2,080	6,300	850	60,700	12,500	5,000	3,800
Actual SS Load lb/day	12,300	1,460	4,280	730	32,700	9,800	20,000	10,600
SS removal %	83.3	97.5	97.5	82.5	95	91	97.0	85
TOTAL No. of Industries.	90	16	45	25	210	45	30	15
No. of major Industries	10	4	7	2	23	11	4	2
Main waste contributors	distillery brewery plating	meat packing plating canning	Food process plating	Textile	Meat packing tanneries	Textile plating	Auto-motive plating Tannery Chicken killing	Tannery Food process

SUMMARY OF MUNICIPALITIES WITH COMBINED TREATMENT IN ONTARIO (cont'd)

	A	B	C	D	E	F	G	H
Estimated Industrial Contribution								
Flow (%)	56	21.5	25.7	31	43	22	54.6	28.5
BOD (%)	90.0	80	74.8	75	51	17	32	79
SS (%)	58.5	58.2	46.7	17	58	14	12	66
Remarks	overload plant widely varying pH affects process	no major operating problems					Widely varying load. Plant operates well with low MLSS	Increased maintenance at STP due to tannery

of rather severe overload are able to perform their function efficiently.

Summary and Conclusions

Perhaps the best way to summarize and conclude is to state what should now be obvious: - treatment of industrial wastes at municipal treatment plants is not just a simple matter of conducting the industrial process waste flow to the municipal system. Instead it involves the careful consideration of all the factors presented here and a spirit of good faith and co-operation between municipal and industrial officials.

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BANQUET NIGHT

BANQUET SPEAKER
J. J. McGILL

BANQUET ADDRESS

"CANADA'S CENTENNIAL

CELEBRATION"

BY

JOHN J. McGILL
VICE PRESIDENT
IMPERIAL TOBACCO COMPANY (ONTARIO), LIMITED,
AND A MEMBER OF THE CENTENNIAL SPEAKERS' BUREAU

I am a Canadian and extremely proud of it. I have had the fortunate opportunity of travelling back and forth across this wonderful Country of ours many times. With two or three exceptions, if you name a place of any size, odds are that I have been there - from Courtney and Port Alberni on the outside fringes of Vancouver Island to the outports around St. John's, Newfoundland. Canada is truly a wonderful Country.

To quote Bruce West - a well-known columnist with the Toronto Globe and Mail - "We hold a huge domain, which is more of an empire than a mere Country... it is so big that we who live in it, tend to rattle around in it - each group in its own compartment and not particularly interested in the other". May I add, "that's a tragedy indeed."

But, let me quickly take you across Canada, as Bruce West sees it.

"On the map of Canada, he says, Cape Breton Island looks like a rather insignificant lump on the face of Nova Scotia..how startling it is to find that it is a beautifully rugged land with highways which climb so high into the sky that occasionally the road is kissed by passing clouds. Farther to the East, of course, lies the vast and spectacular island of Newfoundland, dotted along its coast with such colourful-sounding hamlets as Leading Tickle and Great Pink Gut. All of Canada's Maritime Provinces are loaded with thrilling vistas, - with their forests and fields seemingly made more deeply green by the moist breezes from the sea, - and here and there rocky coastlines jutting out stubbornly against the onslaughts of the Atlantic's relentless breakers. Moving westward, there is Quebec, which cradles in its arms the final reaches of the mighty St. Lawrence. It is easy to understand why the French Canadian so proudly - and so jealously - surveys the beautiful land to which he and his forefathers have always held a particularly close attachment. Ontario, many of us know fairly well, although, perhaps, not as well as we should. The prairie lands of Manitoba and Saskatchewan have a broad roominess that makes the Easterner squint his eyes in adjustment to such unusually wide horizons. In Alberta, you will find both the waving seas of grain and the soaring grandeur of the great mountains, - through which the magnificent Trans-Canada Highway now wends its wide, - smooth way... to British Columbia which offers perhaps the greatest variety of sights of any Canadian-province. With its snow-capped peaks just behind your shoulder, you can gaze out upon the Pacific and muse that somewhere beyond, where the sea meets the sky, lies mysterious Asia".

That's a magnificent bit of descriptive writing..indeed we do possess a beautiful country, rich in history and wealthy in geography.

We frequently hear that Canada is an economic monstrosity. Perhaps this was a justifiable point-of-view before the era of modern transportation. Surely this is no longer so... we've been blessed with natural resources that are the envy of all countries throughout

the world...and it seems to me almost invariably nature insists that man must roam far afield, pay a price in adventure and hard work, and reap her benefits. She seldom drops rewards into your lap...I have never heard of gold - in its primary state - being found in New York City - nor of people drilling for oil in Detroit -nor of wheat growing at the corner of State and Madison in Chicago. There is an old saying, 'gold is where you find it'...and the same applies to iron ore, to forests and to wheat growing land. Well, in Canada we have found it but we have had to roam far afield.

We accuse ourselves of having sold out our **birthright** to American capital - and to a degree - I agree we have. It is a pity. Canadians were not able to develop things with our own money. However, today we must see ourselves as a young Country that grew rapidly but did not have time to generate its own capital. Let's not condemn ourselves for it - it is done - that is behind us. It is a penalty we'll continue to pay for through the accelerated advances within our economy. But, maybe the rewards are worth it. However, we're speaking of right now, as we approach the celebration of our first Centennial birthday. I would like to quote a sentence from a recent article by Mr. John Pattison, economic adviser to the Imperial Oil Limited, who says, in part, "no thoughtful Canadian economist is going to question Canada's economic potential." Furthermore, he asserts, "fulfillment and survival depend on the qualities of the people, much more than the qualities of the real estate". Later, in the same article, Mr. Pattison questions a popular notion, "that Canada's growth will be frustrated without a continuous supply of foreign capital. "The fact is, he claims, that for its size, Canada has been one of the largest generators of capital in the world; however, he intimates that the way we use our capital is of the utmost importance to Canada's economic future." I have not done his article justice with those few quotes taken out of context from the whole. However, he does point out that, "Platitudes and pious hopes are no substitute for policies", and his warnings should not fall on deaf ears. We are very local in our thinking which perhaps is understandable, because of our vast geography - and it may well be - that our 100th Anniversary party - our Centennial year celebration - will prove to be a unifying influence of major proportions. But we must know more about one another, about the developments taking place in the Maritimes, about the

true ambitions of that lovely Province of Quebec where, to quote Mr. Halliwell, Financial Editor of the Toronto Telegram, "So much positive, creative thinking is taking place in its desire to make a place in the sun for her sons and daughters"...We have to know more about our Country and think more about Canada...and perhaps less about the little community of South Overshoe, or wherever it is we live.

Speaking about Canada as a whole, I personally quarrel with those outsiders who accuse us Canadians of not being sufficiently venturesome in developing our own Country. This is only another way of saying we lack boldness - and that is utter nonsense. We have proven ourselves venturesome enough in time of war - the reputation of Canadians is first class in every arena of war in which we have been involved. Also, we have been bold enough in times of peace to open up even the roughest, most unyielding parts of our Country. We have been lacking in speculative capital but we have not been found wanting in desire, in brain power, nor in basic know-how. We have not, as a people, had a long range opportunity to accumulate much excess, or extra risk capital, because high taxation became a way of life with us before any sustained period of prosperity came within our horizons. But as a people, I believe that we have a strong moral fibre, with a great, in-built, sense of honesty and desire. Despite all the criticisms by ourselves and from outsiders, we have built a wonderful Country. As businessmen, we are all aware of the steady growth in our Gross National Product figures... as ordinary citizens, we cannot help be aware of the tremendous day by day developments within our cities - and indeed within all of our provinces. We are all conscious of the fact that with each passing year, our undeveloped frontiers are being pushed further and further back. Despite all our bickerings, we have a surging nationalistic pride - a little neurotic at times - but, healthy and hopefully growing...and I think this is most strongly felt and asserted, when we have an opportunity to travel abroad. We are very anxious then to let it be known that we are Canadians.

Well, within a very, very few months, we are going to have a full opportunity to demonstrate some of this pride, as the bells peal out to announce the beginning of our Centennial year of celebration...and both the guide

lines and outlines for a marvellous 100th year anniversary have been prepared for us - by your Centennial Committee.

I use the words, "guidelines" and "outlines" advisedly, because this is a true birthday party - a sort of big family affair. Your Centennial planners have probably gone beyond your fondest expectations in making preparations for us. However, to get the warmth into the celebrations calls for overall participation by our Canadian people and that is the part you and I and all our friends and communities must play.

I am sure we have all been invited at one time or another to a big, beautifully planned party, wedding reception or social event - where the best caterers were hired. The food was superlative - even the weatherman was kind - but, the family or host somehow or other never really got involved. The family thought they could pay somebody to run everything for them. The result was that the event almost came off, nothing really went wrong, but there was a lack of warmth, of participation - you know what I mean. The affair was dutifully covered by the press, nobody could find fault with the arrangements, everything was excellent. Except no one really enjoyed themselves.

We just can't let this happen to our beautifully planned 100th birthday party.

The major events already arranged are so numerous and so versatile in their scope that without too much community participation, it will still be - in the eyes of the world - a most memorable occasion. But, it is not the eyes of the world in which we are principally interested. Our Centennial Celebration has been planned for Canadians - for you and me, our families, and for all the people like us, across this land of ours.

Now, let me rather briefly sketch out for you some of the plans. I am sure you will find the list of projects most impressive. First, though, I would mention the Centennial Commission is an agency of the Federal Government responsible for the overall promotion of Centennial activities. It spends money in three major areas of which one area is the Confederation Memorial grants program in which $2,500,000. has been given to each Province to construct an edifice of permanent value...among these is the Fathers of Confederation

Memorial Centre in Charlottetown...and the Ontario Centre for Science and Technology being build in Toronto. Secondly, the Commission administers grants to the provinces on the basis of one dollar per capita of population as of June, 1963. This money is being used for projects of lasting value in the educational, historical, cultural and recreational fields, The federal contribution must be at least matched by both the provincial government and the municipality or other initiating agency. Under this scheme, you find such diverse projects as a Japanese garden in Lethbridge, Alberta, the reconstructions of an old fort in Sept Isles, Quebec, and so on. The Commission's third broad category of involvement includes projects of national significance. Among these, are the Centennial Youth Travel and Exchange Program. Last summer, many, many young people spent at least two weeks in a province other than their own...and by the end of the Centennial year thousands more will have seen much of their own Country.

Our Centennial officially gets under way at the turn of midnight on December 31st. Plans have been made to have all church bells and carillons across Canada peal out the glad tidings from 12:00 p.m. to 12:05 a. m. in the various time zones across the Country. They'll ring again at the same hour on July 1st and we look for huge bonfires to be set during these first few minutes of 1967 and again July 1st in Ottawa, and in all our provincial capitals. The projects planned cover the history of our Country - the past, the present and the future.

Incidentally, three days will have special ecumenical treatment, January 1st, July 1st and Thanksgiving Day...the program calls for a Centennial hymn to be sung in all churches, synagogues and places of worship, as a reminder that our community roots are based on spiritual values.

The Centennial Commission has some very major plans to commemorate our history, past and present. The Confederation Train commences its tour on January 9th, 1967, in Victoria moving eastward across the Country, stopping at the major cities in each province. By mid-December, the train will have visited some 83 sites. This train will consist of 15 units, six of which will be exhibit cars. Every skill of the planner, the showman, and the historian is being put into this travelling exhibit which will tell Canada's story from its beginning.

The Centennial train will be supplemented by eight mobile caravans which will move into 670 communities that the train will not touch...the Centennial caravans consisting of 8 units, each measuring 73 feet in length, will tell virtually the same story of Canadian history as does the train. It is interesting to note, when these various Centennial caravans arrive at a town, the four exhibit units will form a large quadrangle...the centre quad will contain regional exhibits...and a small platform at the entrance will permit the staging of local performances. It is my understanding that between the train and the planned caravan routes every centre of 500 or greater population will have been given an opportunity to see this review of Canadiana. I should imagine many smaller cities and towns will gear their major local Centennial undertakings to the scheduled visit of the caravans. It could well prove to be the hub around which local programs revolve...the caravans will operate from May 1st to mid-November, the train from January 8th to mid-December. The schedules are all arranged and the dates of their visit to your community are available from the Centennial Commission in Ottawa, or I will give you some individual dates here today.

A gigantic canoe race has been planned... our history really began with the courageous coureurs de bois, explorers and navigators, who braved the elements, the dense forests and our violent rivers of the North and West to open up a continent to civilization. To recall this essential chapter of our history, 10 to 12 canoes, each with 6 paddlers aboard will race from the foothills of the Rockies to Montreal to retrace the trail our pioneers used in ages gone by. On their gruelling 3,800 mile expedition, the paddlers will stop at many points -on a prearranged plan - and here again is a wonderful opportunity for local communities to organize special events and greet the contestants.

While all this activity is going on, with the Centennial train - caravans, canoe race, etc. - historical pageants will be staged across the Country - to facilitate involvement of individuals and groups in the culture of the past. Pageantry will reach its peak with the Canadian Armed Services tatoo - a colourful spectacle of music, history, pageantry and action. There will be

80 colourful selections in 12 major scenes, with marching bands, pipes and drums, scenes from history, and action scenes from battle. It is my understanding this military tatoo will be staged in 40 differenct locations.

Manv people believe the most concrete expression of a country's vitality is the achievements of its cultural life. Canada has made belated, but very satisfactory, progress in this area. We now have professional theatrical companies, ballet companies, some fine symphony orchestras, and an increasing number of good buildings for the performing arts. The performing arts add two new dimensions to the other arts - that of language and music - the strongest of all bonds of communication between men. Therefore during the Centennial year, a great assist will be given this phase of our cultural growth. The Canada Festival of 1967, with more than 20 professional Canadian Companies will tour our major cities. A combination of highly qualified professional and talented amateur groups will combine to stage these performances across our Country.

The athletic side will not be overlooked. One aspect of this will be a country-wide participation by school children in a physical fitness program. There will, of course, be many spectacular events such as the Pan-American games at Winnipeg.

There will be so many things - I could bore you with the details. The Eskimo Village, the Indian Village, special films, local clean-up and paint-up undertakings, a tree and shrub planting program, etc. etc., but I will only specifically mention a few more projects. One deals with our children, another with sharing our good fortunes with those less privileged... permit me to deal with this latter point first and I will be as brief as possible. It would be a shame - in this troubled world - if we Canadians, in the course of our birthday planning, forget about the less fortunate people in so many other parts of the universe. In fact, when you think about it - it would be downright selfish. Your Centennial Commission is hoping, through public subscription, to raise something in the neighbourhood of at least 10 million dollars, to give to some of the less privileged peoples in other parts of the Globe. This will be done through the International Co-operation

Year Organization. The Commission has started off the fund with a grant of 250 thousand dollars. It makes me feel good to think about it. The minimum total of 10 million dollars only represents about 50 cents per person of our population - just meditate for a moment - how much that will benefit even a limited portion of the less fortunate folks - in less privileged areas of our world. I think it is a small, but wonderful gesture and we will be sharing our birthday party.

Now another project I want to mention is directed towards our youth. If we are ever going to truly unite this Country of ours, it is going to be because the young folks get to know one another better - much better - and the only way this can be accomplished is through understanding. The only way I know in which to develop true understanding is for our young people to visit back and forth between the provinces. I sometimes think - when the time comes - that I would like to devote a portion of my retirement years to this visiting program. Particularly, as it pertains to the Provinces of Quebec and Ontario - because I am in love with both and have close friends on both the French and English side. But all provinces will be involved.

Now, it should be noted that the Centennial Committee's plan is really only an extension of a program previously started within some of the provinces... the Federal-Provincial youth program is one of the best known of all the Centennial Commission's projects. From the time of the formation of the Commission, the need for inter-groups and inter-regional understanding was recognized, and it is the youngsters who will get to understand each other so much better, if given a reasonable opportunity. In 1964, the Commission, in co-operation with the Provincial Governments, began a pilot travel project involving 936 high school students in the 15-17 year age bracket. In 1965, the number of participants was increased to 3,072 and a further increase to 3,840 is planned for this summer of 1966.

1967 will see this Community Exchange Program reach a high level of participation - and if we achieve reasonable levels of understanding and appreciation among our youth across Canada a platform for true unity will be

established. Children are not born with bias and prejudice, they acquire these from their parents and older associates, and I guess to some degree, from history.

Now, I would like to say a few words about Expo '67. I'll be as brief as possible, but, in my opinion, it is going to be a tremendous show. Mayor Jean Drapeau and his associates deserve so much credit for their imagination and persistence...I saw the beautiful site in its infancy and frankly wondered if the plans for and around St. Helens Island could ever be completed. Well with some adjustments from the original, they are going to be. Managing Director, Bob Shaw, has publicly stated on numerous occasions that his plan is running on time - or at any rate is going to meet its schedule. Bob Shaw and his group are another strong and visible evidence that Canadians know how to do things - on a very large scale - when challenged to do so. By all means, I urge you to visit Expo...take time for a look around Montreal; to those of you who have not been there for some years, I can only say the developments in that bustling, colourful metropolis will astound you...and if you have time, take a little motor trip through at least a portion of La Belle Province - it will be a rewarding experience. But, don't let a planned trip to Expo '67 - by some association or group in your community - in any way represent your community effort for the Centennial Celebration. The expression of local community pride in Canada's 100th year of achievement, properly done, with full participation, is going to be the grass roots of our yearlong birthday party. It doesn't necessarily have to be something big. Just so long as the undertaking arouses enthusiasm and support of the people where you live... it is in the aggregate that all the smaller efforts become important in a community.

It was intimated to me that I should suggest some Centennial projects for your consideration and possible participation. Frankly, I am not qualified to do so - and I think it would be presumptious on my part, even if I had the necessary knowledge of your individual desires and interests. However, many, many, many, community projects are in full swing - the list seems endless - but, here are a few examples: a \$60,000 library for Pincher Creek, Alberta, a \$150,000 swimming pool for Matane, Quebec, a \$20,000 Municipal building for Dresden, Ontario, a museum

in Little Current, a library in Bracebridge and so it goes.

Remember, under the Federal - Provincial Centennial Grants program... the Federal Government undertakes to contribute $1.00 per capita per province for approved projects - of lasting merit - providing the Provincial Government and the municipality or other initiating agency concerned together pay $2.00 per capita. And don't forget the clean-up, paint-up campaigns, nor the tree and shrub plantings. It may not sound like much but, in some communities, the school children are to be organized into tree planting projects and beautiful living memorials of Centennial year will result.

Our Imperial Tobacco Company is formally participating in both Expo '67 and in the Centennial program. In addition, less formally, we'll undoubtedly be involved in many, many other areas. In connection with the Centennial program - the Imperial Tobacco Company is donating $60,000 in prizes to sponsor a nationwide competition for the best creative, critical or analytical work covering the crucial 33 year period from 1967 to 2000 A. D. The project has been named "Canada - 2000 A. D." It is open to any Canadian citizen living at home or abroad, and a competitor may deal with any aspect of Canadian life. We hope that "Canada -- 2000 A. D." will present a challenge to many hundreds of thoughtful Canadians who care about this country of ours. Many, we hope, will have ideas of how it may or should develop over the next 33 years, and what we may expect in the year 2000, which begins a new century. A most imposing list of five judges has been arranged and competitors are required to submit an accurate abstract or summary, not exceeding 2,500 words in length, by July 15th of this year. By November 1st, 1966, the judges will have selected the 10 top abstracts. These early winners will be informed and each of the ten presented with $1,500. They will each receive an additional $1,500 when they fully develop and submit their individual projects. These ten people will then have a full 10 month period in which to develop their thesis or full length book and this must be delivered to the Administrator of the contest by September 1st, 1967. We, at Imperial, hope

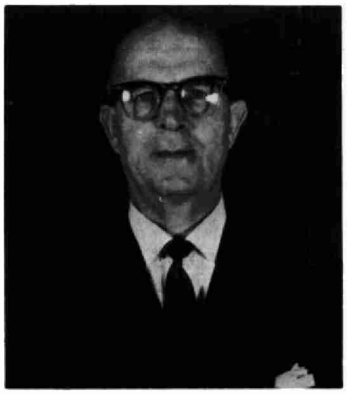
that among the winning entries new and exciting ideas for Canada's future will come to light. On October 1, 1967, the winner of the Grand Award will be decided and he or she will receive an additional $30,000. So, the eventual winner will receive $33,000 in total and the other nine finalists - assuming completion of their writing project - will receive $3,000 each. This makes a total of $60,000 in prize money.

Now this contest "Canada - 2000 A. D." is, of course, a major company undertaking. Imperial Tobacco has put a great deal of thought and money into it already but it is only one of many, many good plans being developed by companies across the Country - so you ask - what can we do? Now I don't know whether you mean as an association or individually as members of your community. Whichever it is, I am not qualified to attempt to help you arrive at a decision, but I urge you - do something to show your pride, your appreciation of the past, and your enthusiasm for the future. Write the Centennial Commission if you will, c/o P.O. Box 1967, Ottawa, or put your thinking cap on. If it is a case of helping out in your various communities, I would suggest you consider tieing in with some section of the travelling Centennial Exhibits. They will give you the big base platform and you people can add the intimate, local colour.

One last thought. I would like to leave with you, "No Centennial Celebration has been possible for any nation since the United States celebrated its first century - nearly a hundred years ago". Ours is going to be a very, very, big and memorable occasion. Excitement you can't possibly feel now is going to grow with the coming months. Centennial enthusiasm is steadily developing. I say to you all, remember that this Centennial of ours is without precedent and without any hope of repetition. Canada needs this great unifying force, a public and an individual demonstration of our faith, love and good will for this Country of ours and for all the people in it.

This Centennial birthday party will be another heritage we leave behind us. Remember, not one of us will have a second chance...we simply won't be here to try again.

SESSION CHAIRMAN
R. E. TAIT
ASSISTANT CHIEF
DEPARTMENT OF NATIONAL HEALTH
AND WELFARE



R. S. ASTON

"ZINC RECOVERY FROM VISCOSE RAYON EFFLUENT"

BY

R. S. ASTON

CHIEF CHEMIST
COURTAULDS (CANADA) LIMITED

Read By
J. MORRIS, CONSULTANT

The characteristics of the waste liquor flowing from a Viscose Rayon Plant will vary from plant to plant according to the process details in operation at each site. All Viscose Rayon plants will produce both acidic and sulphidic wastes with the acidic waste being the predominant portion. The acidic waste contains zinc sulphate whose volume and concentration will vary according to the type of yarn being produced.

Table 1 shows the approximate flows and concentrations for the various yarn types.

TABLE 1

Type of Viscose Yarn	Flow of Effluent per lb. of Yarn	% $ZnSO_4$
Textile	25.0 gallons	.012 - .020
Staple Fibre	15.0 gallons	.014 - .020
Tire Yarn	40--50 gallons	.040 - .055

Table 2 shows the approximate weight of zinc sulphate lost per hour in the acid effluent from a yarn production rate of 2,000 lbs. per hour.

TABLE 2

Type of Viscose Yarn	Production per Hour	Weight of $ZnSO_4$ per hour
Textile	2,000 lbs.	60 - 100 lbs.
Stable Fibre	2,000 lbs.	40 - 60 lbs.
Tire Yarn	2,000 lbs.	360 - 495 lbs.

The Cornwall plant produces all three types of yarn and in consequence its effluent problem is more acute from the zinc disposal point of view than a single product plant producing either Textile or Staple Fibre.

Where treatment of acid effluent is in operation, the conventional process usually involves treatment with lime, settling and collection of resultant sludge. Increased amounts of zinc adversely affects the sludge settling rate, the sludge dewatering process, and increases the amount of sludge to be handled, which in general is responsible for an increase in effluent treatment costs. Where discharge to receiving waters is practiced the increase in zinc discharged tends to exceed acceptable limits.

As production rates of Tire Yarn continued to grow, attention was focussed on the possibility of segregation and subsequent recovery of some of the more highly concentrated fractions of the various effluent streams.

The first approach was by evaporation. The economic feasibility of this scheme depends upon the capacity of the plant to provide the extra steam, without extending existing steam raising or evaporative equipment. Where this consideration is favourable, recovery by evaporation has certain advantages at plants where treatment of acid effluent is being practiced. The main advantage is that the acid content as well as the zinc is recovered with a consequent reduction in effluent treatment costs. The main disadvantage is that it provides no solution for the amount of zinc discharged at low concentration and in large volume streams. Where effluent

treatment is not practised these high volume streams constitute a major source of effluent pollutants.

The possibilities of Ion Exchange for reducing the zinc in the acidic waste was first examined by Courtaulds (Canada) Limited, in Cornwall, in the early Nineteen-fifties. Since that time, there have been relatively few technical papers published which mention this applications.[1, 2, 3, 4] Mindler[4], in 1963 referred to the existence of six such plants in various parts of the world.

The technical and economic feasibility of Ion Exchange for Zinc Recovery was explored by a bench scale pilot plant. The main purpose of this exploratory work was to examine the life of the resin and determine whether any poisoning could be expected from low concentration organic surfactants present in the effluent stream. The design of this pilot plant was provided by the courtesy of Permutit Company.

The resin used was Permutit Q, a cation exchanger of the sulphonated polystyrene type, operating in the hydrogen cycle and regenerated with sulphuric acid.

$$H_2R + Zn^{++} \text{ ------------------ } ZnR + 2H^+ \quad (1)$$

$$ZnR + H_2SO_4 \text{ ------------------ } ZnSO_4 + H_2R \quad (2)$$

Equations (1) and (2) represent the reactions occurring in the absorption and regeneration cycles.

Pilot Plant Details

A 20 inch resin column of 3/4" diameter was used, preceded by two quartz filters to remove suspended matter. Influent and regenerant liquors were fed from twin 20 litre bottles at an operating head of 7 feet. The operating conditions were as follows:

1.	Cycles per day	=	10
2.	Influent rate	=	65 to 70 ml. per minute
3.	Influent Analysis	=	.098 to 102% $ZnSO_4$
4.	Absorption Cycle	=	96 minutes
5.	Regeneration Cycle	=	48 minutes
6.	Regeneration Rate	=	35 to 45 mls. per minute

7. Analysis of Regenerating Liquor = 20% H_2SO_4
8. Temperature of Feed and Regenerant Liquors = Ambient

Continuous cycling was made possible by means of a specially designed valve arrangement which opened or closed the rubber tubes feeding the various solutions. The cycles were controlled by a timing mechanism shown in the previous slides. Elution graphs were made by analysing fractions of the regeneration product during the regeneration process. After 300 cycles the shape of the elution graphs remained unaltered and it was concluded that no poisoning had occurred. (Figure 1)

Following the successful pilot plant trials, a survey of plant drains was undertaken to pinpoint the zinc bearing streams. The survey showed that of 12 drains tested, 95% of the zinc wastes were confined to 3 drains only. The balance of 5% was spread over the remaining effluent streams, which were largely located in deep and inaccessible sewers, and were unsuitable for recovery on many counts, the principal ones being of high volume, relatively high suspended solids and a prohibitively high calcium and magnesium content.

A plant was then designed based upon treating effluent with the following criteria:

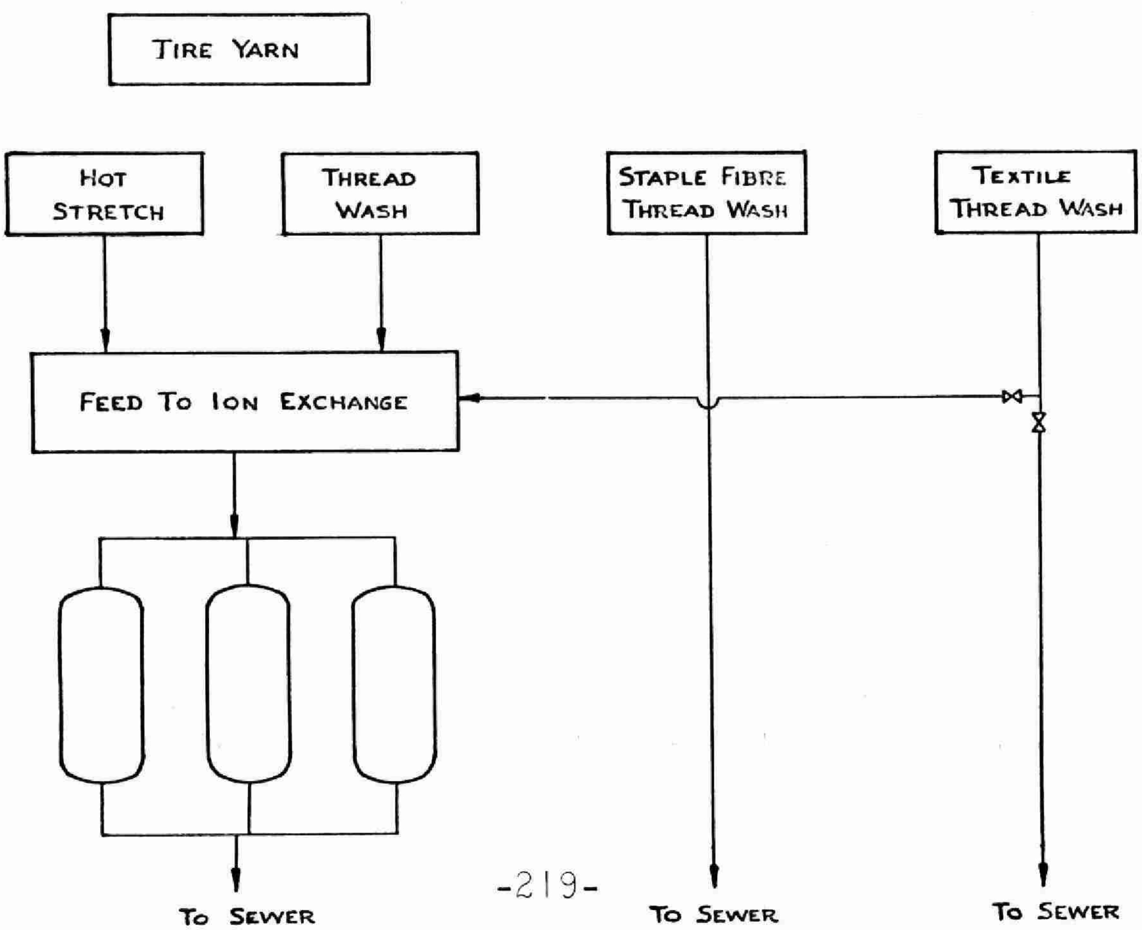
1. Total electrolyte concentration = $>$ 1.0 %
2. Optimum zinc sulphate content = 0.08 %
3. Calcium and magnesium hardness = $1.0/10^6$
4. Turbidity = $>$ 17.0 Hellige-Units
5. Ratio of Zn^{++} to Na^+ = 1.2

Figure 2 shows the main streams of zinc effluent and of these Tire Cord Hot Stretch Overflow and its associated thread wash were chosen as the first liquors to be treated since they satisfy most of the desired conditions. They are relatively clean, are suitably located for admixing and produce an effluent whose characteristics approach the desired criteria.

FIG. 1

EFFLUENT STREAMS WITH HIGH ZINC CONTENT

FIG. 2



Approximate analyses of the two streams chosen for treatment are shown in Table 3.

STREAM ANALYSES - TABLE 3

Hot Stretch:	H_2SO_4	=	3.0 to 4.0%
	$ZnSO_4$	=	0.7 to 1.0%
	Na_2SO_4	=	1.5 to 2.0%
Thread Wash	H_2SO_4	=	0.25 - 0.30%
	$ZnSO_4$	=	0.020 - 0.030%
	Na_2SO_4	=	0.5 - 0.7%

The streams are blended to give a composite liquor with a total electrolyte content of 1.0% and a zinc sulphate concentration of 0.8%; the temperature is approximately 140°F.

Process Flow Sheet

The Ion Exchange process is shown in Figure 3. The composite liquor is filtered through gravity quartz filters to reduce the turbidity to below 17 Hellige-units. The resulting effluent is passed through a bed of cation exchange resin (Permutit Q) at a flow rate of 6 gallons per minute per square foot of bed area. The effluent from the resin bed is used for backwashing both the resin bed and the quartz filters. Since it is extremely clean and relatively warm, it is also used for making up the volume in the hot stretch system, resulting in small savings in steam and acid. When zinc starts to leak through the resin bed, the resin is regenerated with sulphuric acid to produce a solution containing approximately 10% $ZnSO_4$, 10% H_2SO_4, and 2% to 4% Na_2SO_4 which is returned to the spinning bath. Liquor from Recycle Tank 1 is pumped at a rate of 0.8 gallons per minute per square foot through the resin column until a volume equal to the void volume of the resin has been displaced to the sewer. At this stage, the valve to the sewer is closed and the valve to the product tank is opened. Recycle Tank 2 is then pumped out which displaces a fraction into the product tank. Recycle Tank 3 is then pumped out, which displaces a volume fraction into Recycle Tank 1. Feed effluent is then pumped through the column wich displaces two more fractions into Recycle Tanks 2 and 3. Strong sulphuric acid is then added to recycle tanks 1 and 2

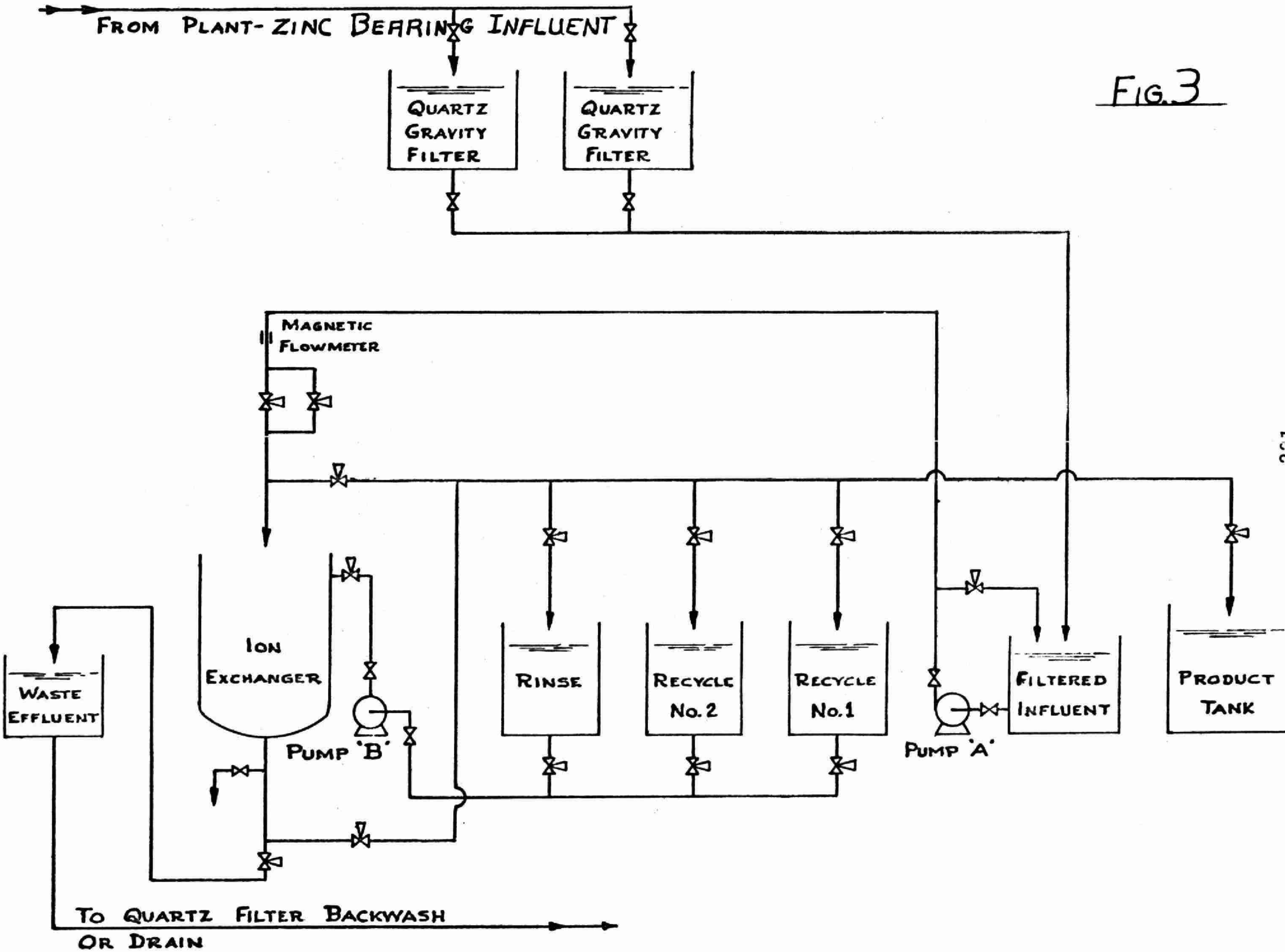

FROM PLANT- ZINC BEARING INFLUENT
QUARTZ GRAVITY FILTER
QUARTZ GRAVITY FILTER
MAGNETIC FLOWMETER
ION EXCHANGER
PUMP 'B'
WASTE EFFLUENT
RINSE
RECYCLE No. 2
RECYCLE No. 1
PUMP 'A'
FILTERED INFLUENT
PRODUCT TANK
TO QUARTZ FILTER BACKWASH OR DRAIN

FIG. 3

prior to the next regeneration. The amount of acid added is equivalent to 9 lbs. per cubic foot of resin volume. After acid addition the acid concentration in Recycle Tank 1 is approximately 25%. This recycling process ensures that the resin bed is cycled by three separate fraction during each regeneration which optimises the recovery of zinc and utilisation of the acid used in the regeneration. Average efficiency of zinc recovery is 92%. Extreme care is necessary when commissioning new plants to set the timing of valve changes. Most important is the pumping out of recycle Tank 1. The flow inside the resin column during regeneration is plug type and after the water in the void volume has been pumped there is a sharp change in concentration. (Figure 4). If the valve to the sewer is turned too late, zinc product is lost and if turned too early, a dilute product results which imposes an extra load upon the evaporative capacity of the Acid Recovery.

The regeneration process is automated and the requisite volume control is obtained by the use of conductivity probes and visual observation of volumes, whereas the Ion Exchange process is tested every four hours by technicians who plot the essential details on a control chart.

Malfunctioning

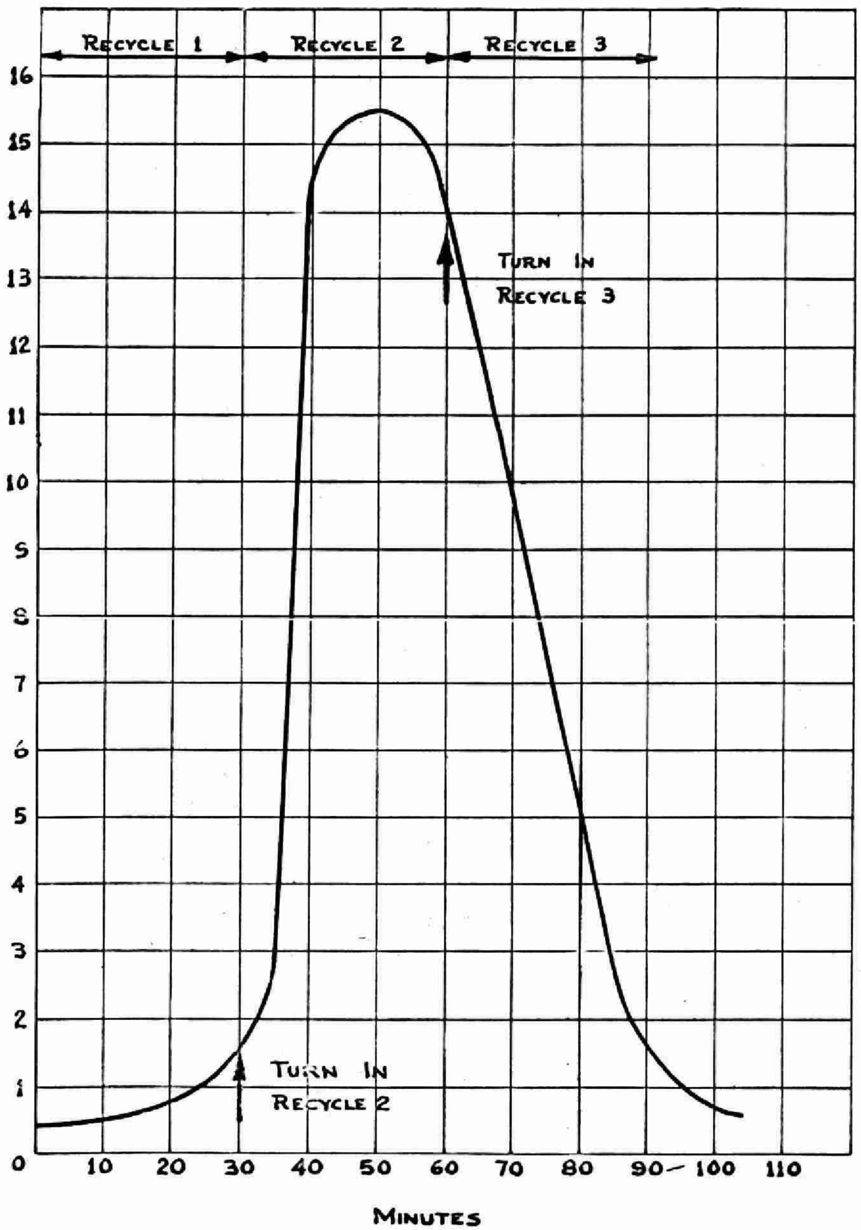
Examination of the control chart readily indicates malfunctioning, which is usually manifested by zinc slippage resulting in an abnormally high zinc content of the effluent after passage through the resin bed. Malfunctioning may be due to operator fault or trouble with the top internals of the unit. Trouble with the internals is usually indicated by an abnormal elution curve which fails to peak sharply within the first 40 minutes of the regeneration process, Figure 5.

Poisoning of the Resin

Some organic amines, and mineral oil will cause fouling of the resin. Although prohibitive poisoning will be indicated in the pilot plant study, slow poisoning may still occur and will be indicated by a gradual fall in resin efficiency. An elution curve from

Normal Elution Curve

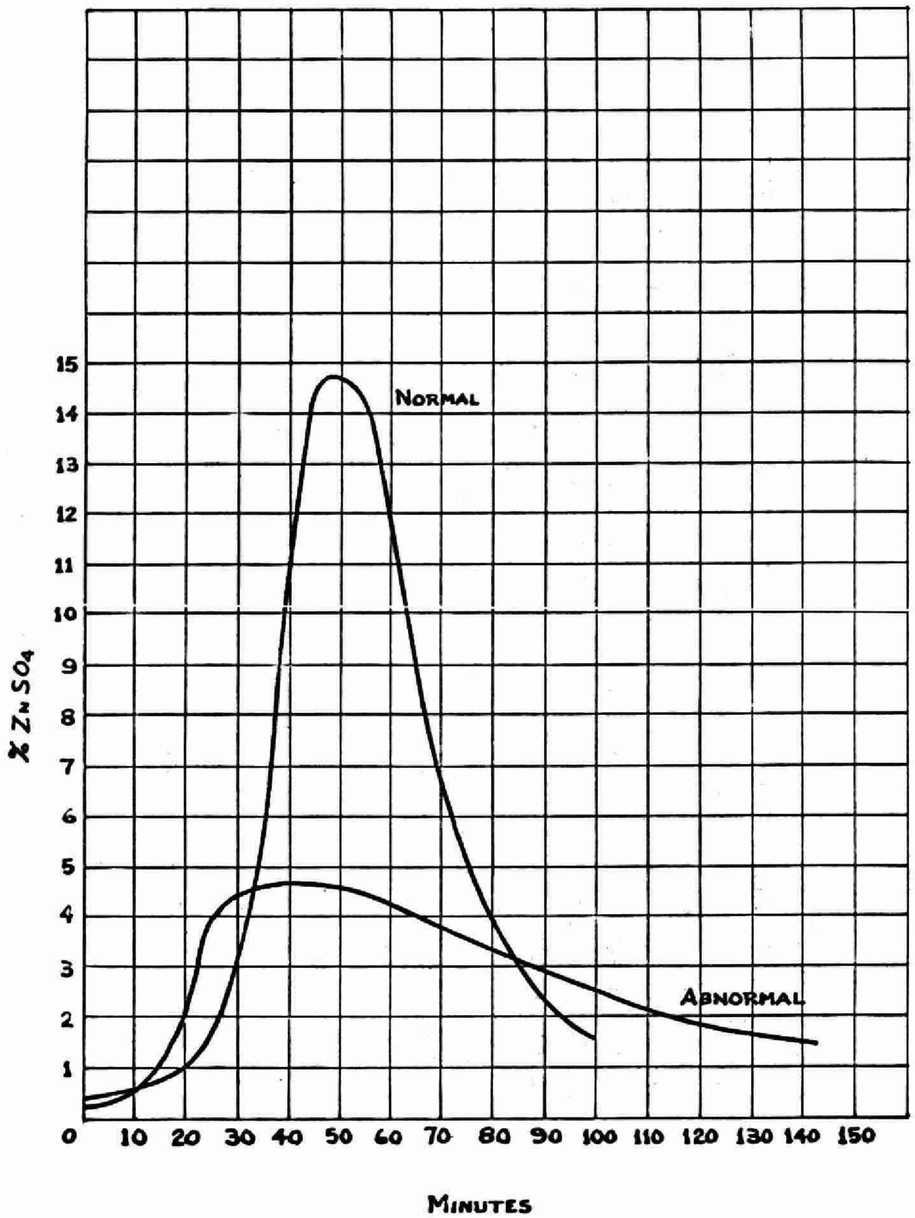
Fig. 4



- 223 -

Regeneration Curves

Fig. 5



a poisoned resin will peak, but will also be dragged out indicating that removal of zinc from the resin is slow and incomplete. The plant at Cornwall has been in operation for six years during which period several different types of spinning bath additives have been in use, without detriment to the efficiency of the recovery process. Analyses have shown that some spinning bath additives are picked up by the resin and removed in the regeneration process. Slow poisoning due to mineral oil has occurred which has necessitated washing the resin bed with 4% caustic soda solution. The frequency of washing depends upon the number of times the bed is cycled per day, and the extent of the fouling contaminant. The resin life is also dependent upon the number of cycles per day. Experience to date indicates that in this particular application the life of the resin is approximately 4 years.

Volume Loading

Normal loadings are quoted as 6 gallons per square foot, but in an emergency this can be raised to 8 gallons per square foot for short periods.

Temperature Effects

A. The resin bed can stand a temperature of 250°F for a limited period without apparent ill effect.

B. A thermal shock of 70°F to 130°F has little apparent effect upon the resin efficiency.

Corrosion

The main materials of construction for the resin columns are: Steel Rubber Lined; Carpenter 20; Hastelloy C; and P.V.C. Rubber Lined Steel and P.V.C. appear to be giving satisfactory service. Hastelloy and Carpenter both showed some signs of slight corrosion after six months operation, but not enough to cause plant breakdown.

Main corrosion problems appear to be associated with recycles Tanks 1 and 2. These are lead lined and experience temperatures as high as 160°F during acid

addition. The lead is attacked and lead sulphate is deposited in various parts of the regeneration circuit. The build-up is not prohibitive, but necessitates plant shut-down for its removal at least once per year.

ECONOMICS

Comparative economics excluding capital costs are approximately as follows:

Gross Savings per lb. of Zinc Oxide Recovered

	Ion Exchange	Evaporation (Single Effect)
	Cents	Cents
Zinc Oxide	15.000	15.000
H_2SO_4 Recovered	0.00	9.000
Re-use of Ion Exchange Effluent	0.193	0.000
Na_2SO_4 Recovered	0.175	2.750
Total Gross Saving	15.368	26.750

Recovery Costs per lb. of Zinc Oxide

Labour	1.750	2.770
Steam (Fuel Only)	1.000	14.400
H_2SO_4	0.307	0.000
R. and M.	0.438	0.360
Power	0.158	0.588
Resin Replacement	0.237	0.000
Total Operating Costs	3.890	18.118
Net Savings per lb. of Zinc Oxide (cents)	11.478	8.632

It is obvious that evaporation by single effect is less profitable than Ion Exchange. In view of this, where evaporation is carried out multiple effect evaporators are usually used. On the other hand, if multiple effect evaporation involves capital expenditure it is generally much higher than that required for Ion Exchange with a resulting increase in pay-out time.

In making a comparison between the two approaches there are three other factors which should be borne in mind.

1. Where full effluent treatment is in operation, the treatment costs will be reduced by evaporation which will improve the economics of this approach.

2. The savings due to sodium sulphate depend upon whether it is recovered and sold as a by-product. Where no sodium sulphate is sold, the cost of evaporation is increased.

3. Where full effluent treatment is not carried out, Ion Exchange is more effective in reducing the zinc pollution load of the plant effluent.

Limiting Conditions of Influent Analysis

The efficiency of the resin begins to fall off when the combined figure of interfering cations H^+ and Na^+ rises above 15 grams per litre (Figure 7). Figure 7 shows the relationship of resin capacity against zinc, concentration, of Na^+ and H^+ rises proportionately. The optimum concentration of $ZnSO_4$ with present effluent conditions appears to lie in the range of .05 to .10%. These limitations have so far restricted zinc recovery by Ion Exchange to plants producing Tire Yarn.

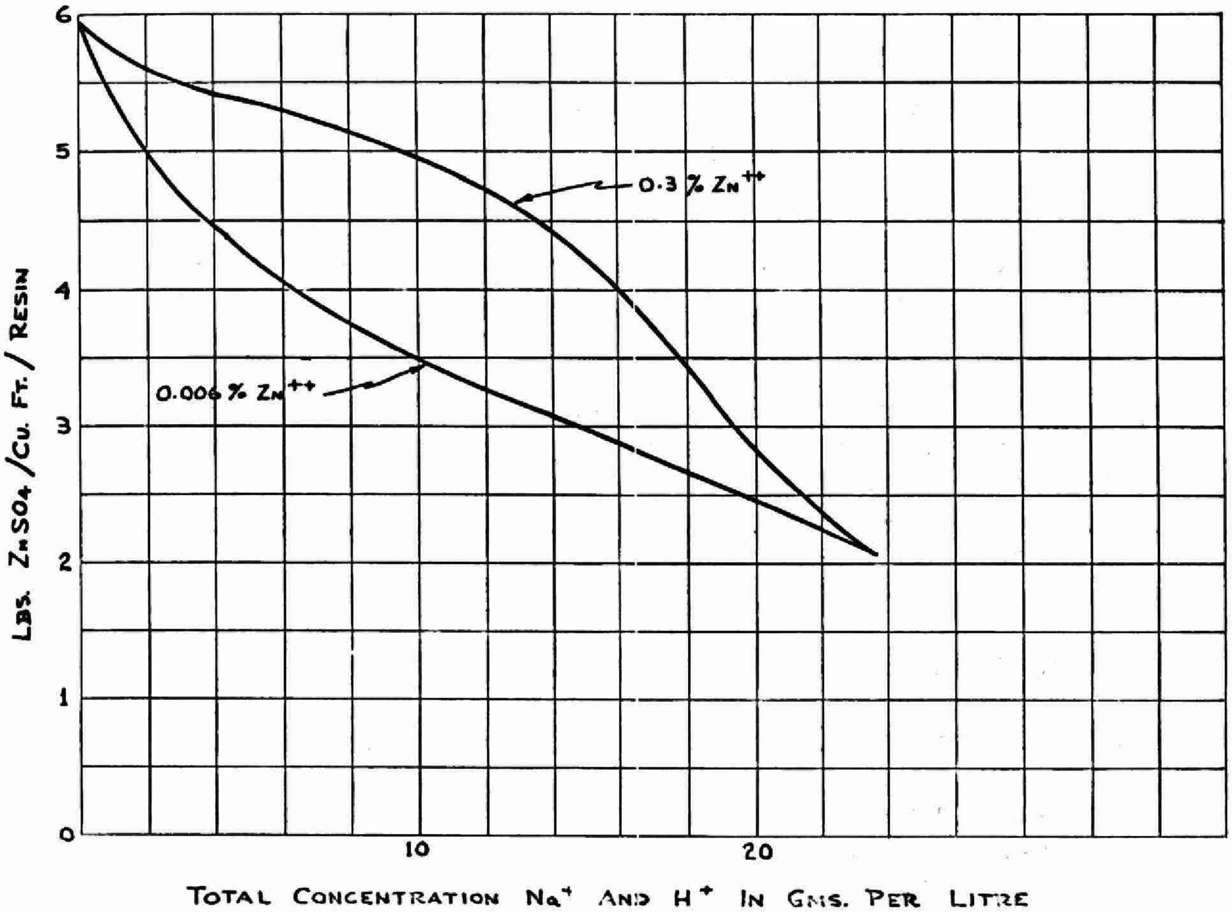
In Textile and Staple Fibre effluent the ratio of sodium to zinc Ions is 26 to 1, compared with 2 to 1 for Tire Yarn. The high Na^+ to Zn^{++} ratio is responsible for several disadvantages when considering Ion Exchange for the recovery of the zinc content from these two effluents:

1. A large amount of soft water is necessary as a diluent to achieve a suitable concentration of total electrolytes.

2. The high Na^+ to Zn^{++} ratio reduces the efficiency of the exchange process with regard to Zinc.

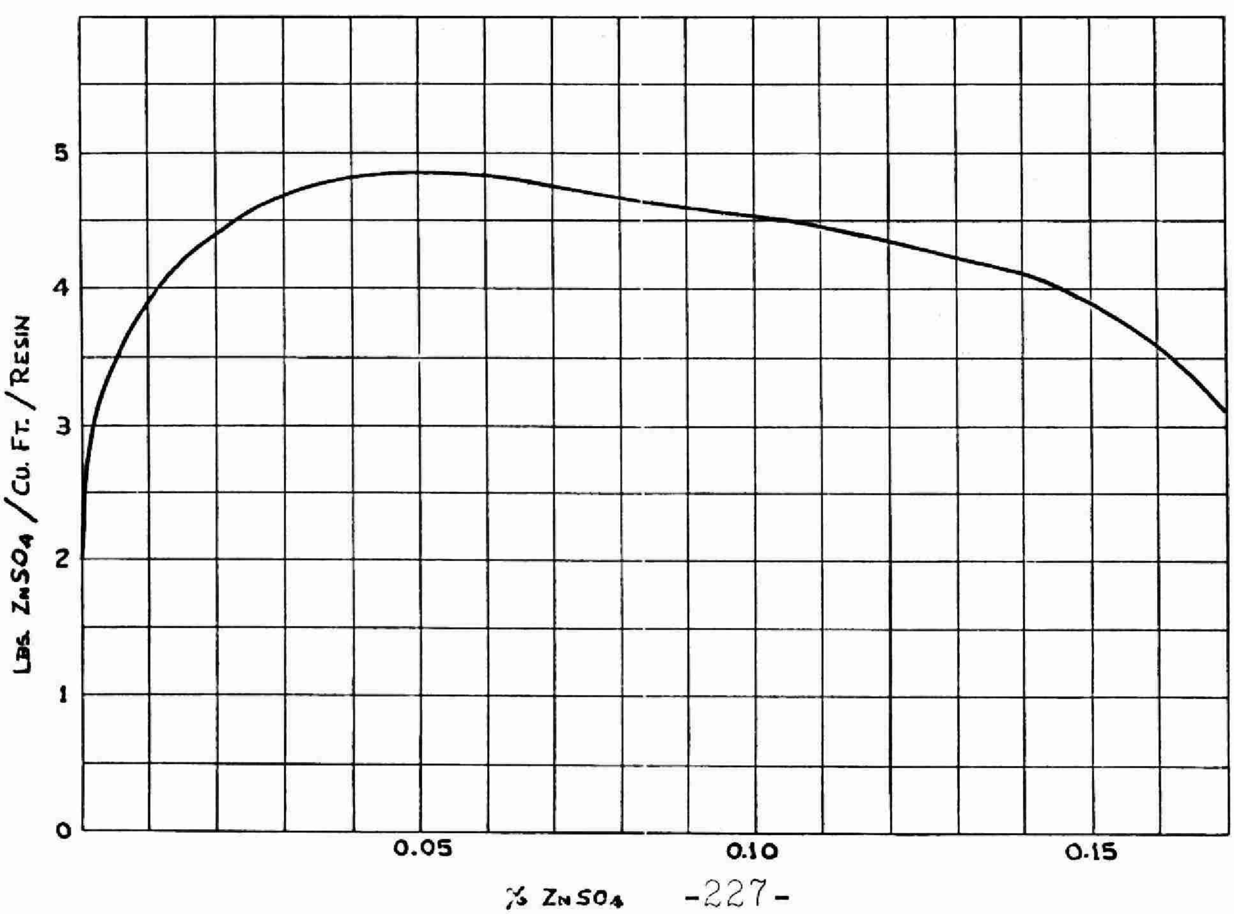
EFFECT OF INTERFERING IONS

FIG. 6



EFFECT OF $ZnSO_4$ CONCENTRATION

FIG. 7



3. Due to the lower content of zinc in this type of effluent the pay-out time for capital costs is much longer than for Tire Yarn.

4. Sodium sulphate recycled to the spinning bath system is higher than that occuring from the treatment of Tire Yarn effluent.

The latter has a mitigating effect upon acid utilization for zinc recovery, and increases acid recovery costs where it has to be removed by crystallation. In the case where sodium sulphate is recovered for sale, then some of these adverse cost factors will be offset.

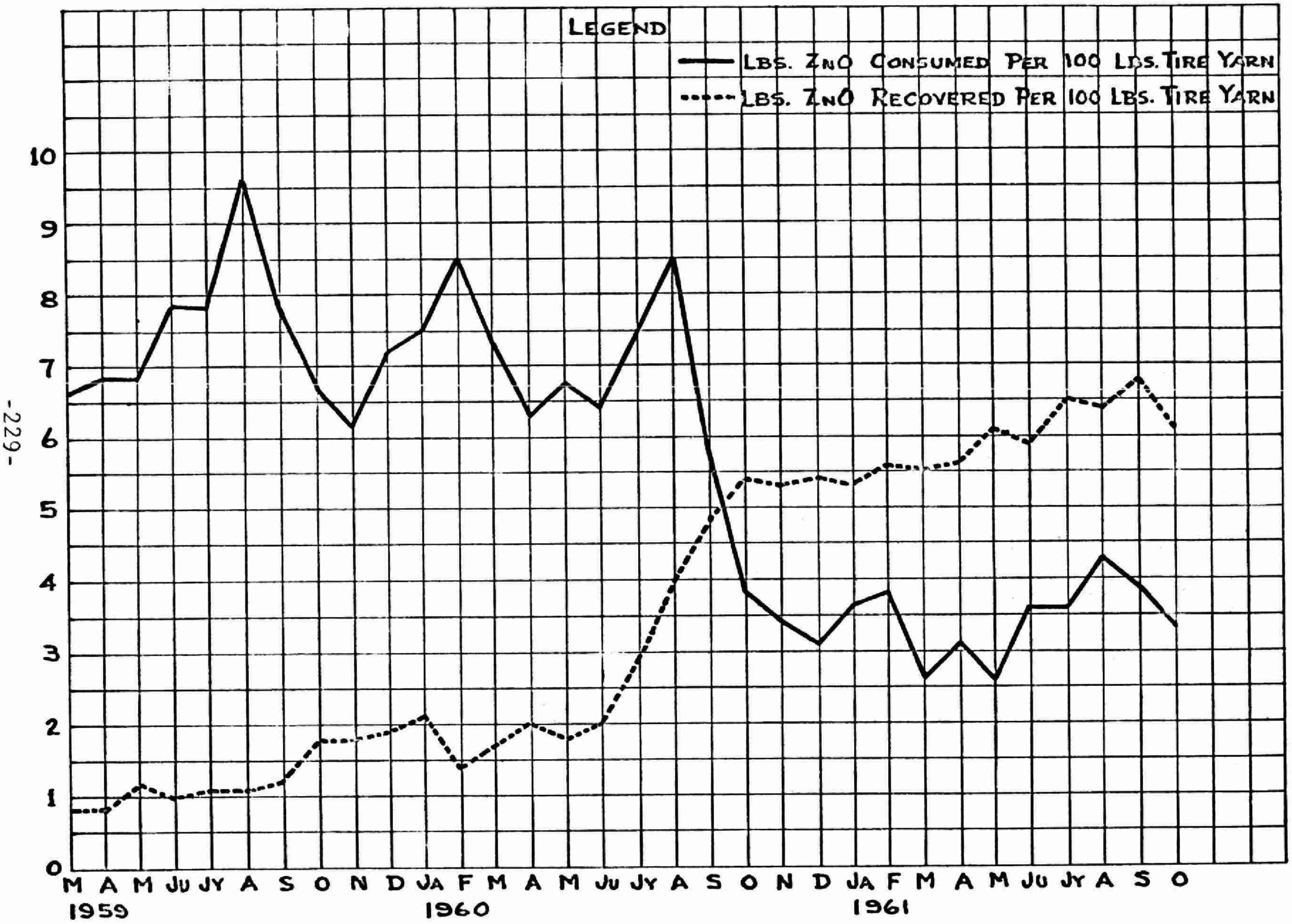
In a multiproduct plant as Cornwall, thread waste from both Textile and Staple Fibre may be blended with Tire Yarn effluent to produce a composite effluent with a Na+ and Zn++ ratio of 6 to 7. The Textile waste is already being dealt with in this manner and plans are well advanced to include the Staple Fibre zinc-bearing effluent. When this is implemented, Ion Exchange treatment of the composite liquor will reduce the original zinc loading to the river by 90%.

Summary

Zinc Recovery by Ion Exchange has been successfully applied to the treatment of effluent liquors from a Viscose Rayon plant. The process is more effective than evaporation in reducing the zinc pollution load, since large volumes containing low concentration of zinc may be treated.

The technical and economic feasibility is enhanced at plants producing multiple types of a product. At the Cornwall plant of Courtaulds (Canada) Limited the zinc discharged to the river has been reduced by 80%.

ZINC RECOVERY



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3. Mindler, A.B., and Paulson, C.F., "Where Ion Exchange Fits in Hydrometallurgy", The Permutit Company, Engineering and Mining Journal, Vo. 156, No. 3-a, March, (1955).

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"SOAP PLANT WASTE TREATMENT"

BY

J. H. CHADWELL

PROJECT MANAGER
ARMOUR GROCERY PRODUCTS COMPANY

INTRODUCTION

There is mounting Federal, State and Municipal concern over pollution in the air and the waters of America.

It is imperative that all business managers understand and accept their responsibility to deal promptly, efficiently and effectively with pollution.

Experience shows that failure to plan for adequate facilities and to institute proper controls at the start can cost many additional dollars in corrective measures.

Further, a reputation for good corporate citizenship is basic in a successful business. Corporate livelihood depends in a large measure on public confidence and public trust.

The story of Armour and Company's new Dial Soap Plant near Aurora, Illinois, and its planning for

proper disposal of sewage waste has been challenging and interesting to those of us who have directed these efforts to maintain this business venture and build public trust.

HISTORY

Armour's Aurora, Illinois, Dial Soap Plant replaces a smaller out-dated soap plant in Chicago. Business expansion and a requirement for modern continuous production facilities dictated a new plant location with room to expand - to produce the leading U. S. toilet soap -- Dial, and such other soaps as Princess. The plant began operations in 1964.

Armour is now almost 100 years old. Yet the technological advances we have achieved in this plant, the ingenuity that created Dial and made it America's best selling soap, are good examples of Armour's youth and vigor.

THE NEW PLANT

The most exicting aspect of the new technology employed in this plant is the Continuous Process for making soap. It replaces the Kettle Method and is by far the most significant change in commerical soap manufacture in more than 140 years!

The Continuous Process not only eliminates many time-consuming, unscientific techniques, but it also increases the capacity of the equipment for making fine bar soap and insures an even high quality product.

It is the largest soap manufacturing plant of its kind in the world and the first totally new, totally modern, soap plant in nearly 150 years!

- Dial Soap starts from natural fats and coconut oils brought to the plant in 6 railroad tank cars daily.

- The crude fats and oils are fed into the two 85 feet tall splitting towers, where a chemical reaction, under sensitive heat and pressure controls, separates them into glycerine and fatty acids.

- The fatty acids are chemically combined with an alkali - caustic soda - inside the saponification towers. This process replaces the kettle boiling method used by soap manufacturers since 1823. Thus the saponification, or soapmaking, process at the Dial plant has been speeded up from several days to a matter of minutes.

- The basic or "neat" soap is pumped into a vacuum dryer where it is solidified to the proper moisture level, and extruded into long chips.

- These chips are conveyed to eleven finishing lines where color, perfume, and Dial's exclusive germicidal agent, AT-7, are added.

- Then the soap mixture goes into a vacuum triplox plodder where it is further blended and compressed, and emerges as a continuous ribbon of soap.

- Now, at an average speed of three bars a second, the soap is automatically cut, shaped and wrapped.

- In one year, 100 million pounds of soap are produced.

The total area under roof is over 11 acres. The warehouse part of the plant is larger than the Toronto baseball park. The railroad dock in the warehouse can handle 10 railroad freight cars at one time; 40 per week are loaded and unloaded, making a train one-half mile long. The plant ships more than 1,710,000 bars of Dial each day - enough to supply 2 bars a day for every family in the Niagara Falls - Buffalo area. The warehouse holds 800,000 cases of

Dial, enough to supply customer needs for eight weeks. The Dial plant is modern, attractive, clean and a safe place to work. There are more than 300 regular full-time production and maintenance employees in this plant.

SITE SELECTION

The Chicago area has many desirable locations available to industry for a new production facility. Aurora, 40 miles west of Chicago, on the Fox River, is an industrial community offering particular advantages to manufacturers seeking a community organized and interested toward making a new business venture a success. Of particular interest in these times, and of special interest to our site location, was the availability of a well-managed municipal sewage treatment facility with capacity to provide limited final treatment service.

Business is a cooperative venture. Planning for this manufacturing facility demanded that arrangements be made with many community representatives and services. The Aurora Sanitary District was one of them.

SERVICE CONTRACT

The contract between Armour and the Aurora Sanitary District provides for well-defined service limits. Noteworthy is a provision that in the event the sewage disposed by the District from the Armour Plant shall exceed these limits, the District shall dispose of such sewage, provided such sewage shall not:

A. Interfere with the biological process of the District sewage works; or
B. Interfere with the proper operation of the District sewage works; or
C. Cause obstruction to flow in the District sewers; or
D. Cause pollution as defined by the Illinois Statutes.

SEWAGE LOAD

New production facilities which do not duplicate, in all or in part, existing operating facilities demand that realistic estimates be made of the quantity and nature of the sewage to be discharged. (Figure 5) This must be done in considerable detail. Too low estimates of wastes at this stage of project planning will result in inadequate facilities. Estimating each small sewage load which contributes to the overall must be done carefully. This process sewage flow sheet outlines the methods used in the planning for Aurora.

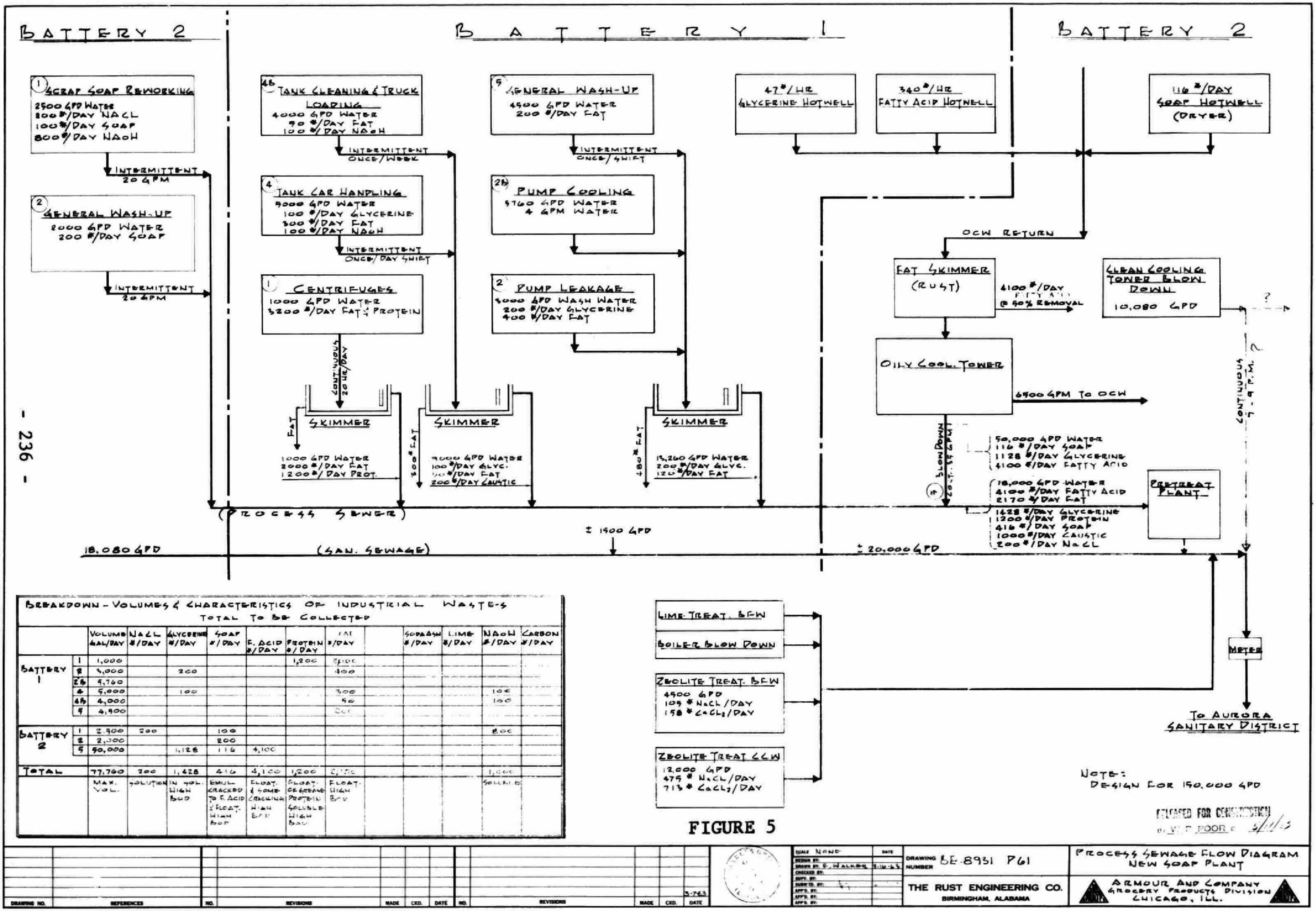
ARMOUR'S PRELIMINARY SEWAGE TREATMENT

With this estimate summary, sewage treatment equipment suppliers were provided with samples of each of the sewage contaminants. They were also provided with the sewage process flow sheet (Figure 6). It was their job to mix the sewage recipe and design a proposed sewage treatment method. The flotation principle was chosen through competition with several treatment process suggestions (Figure 6).

INITIAL FLOTATION OPERATION

Outdoor startups usually come in the wintertime. With inexperienced supervision and operators, it takes time to learn to operate such a system and to adapt this system to actual flow and load conditions (Figures 7, 8, 9).

As a means of control, hourly bottle samples were taken of the influent and effluent from the chemical - flotation treatment plant (Figure 10). The samples were maintained 24 hours and then composited for laboratory analysis. During each 24 hour period, the bottles provided a convenient indication of the loads being accepted by the treatment plant and the effectiveness of this treatment.



BREAKDOWN - VOLUMES & CHARACTERISTICS OF INDUSTRIAL WASTES
TOTAL TO BE COLLECTED

		VOLUME GAL/DAY	NACL #/DAY	GLYCERINE #/DAY	SOAP #/DAY	F. ACID #/DAY	PROTEIN #/DAY	FAT #/DAY		SODA ASH #/DAY	LIME #/DAY	NAOH #/DAY	CARBON #/DAY
BATTERY 1	1	1,000					1,200	[illegible]					
	2	5,000		200				400					
	2b	5,760											
	4	5,000		100				300				100	
	4b	4,000						50				100	
	5	4,500						200					
BATTERY 2	1	2,500	200		100							800	
	2	2,000			200								
	5	50,000		1,128	116	4,100							
TOTAL		77,760	200	1,428	416	4,100	1,200	[illegible]				1,000	
		MAX. VOL.	SOLUTION	IN SOL. HIGH BOD	EMUL. CRACKED TO F. ACID & FLOAT. HIGH BOD	FLOAT. & SOME CRACKING HIGH BOD	FLOAT. OF GREASE PROTEIN SOLUBLE HIGH BOD	FLOAT. HIGH BOD				SOLUBLE	

FIGURE 5

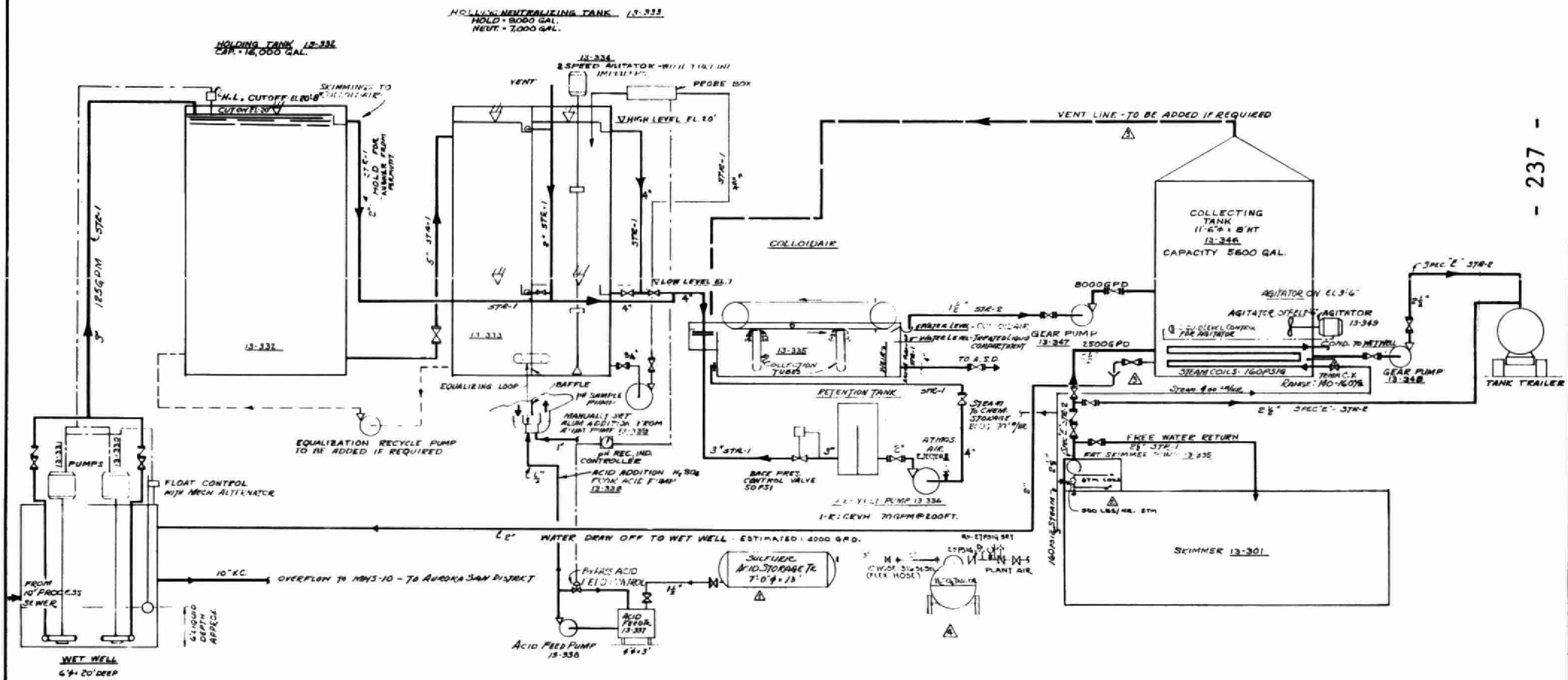


FIGURE 6

Flows Listed Are Design Quantities
All Elevations Are Relative to Bottom of Respective Tanks

RELEASED FOR CONSTRUCTION
BY W. R. POOR DATE 8/6/63

NO.	REVISIONS	MADE	CKD.	DATE
3	ADDED ACID UNLOADING	WCK	WCK	9/16/63
2	IDENTIFIED ALL LINE SIZES, ADDED STM TR. SPEC.	WCK	WCK	9-5-63
1	REVISED STM COILS - REMOVED VENT IN DRAWING		WCK	9-5-63
	CHANGED TANK SIZE	WEIR	WCK	8-28-63

SCALE NONE

DRAWING NUMBER 8931-P60

THE RUST ENGINEERING CO.
BIRMINGHAM, ALABAMA

FLOW SHEET
WASTE WATER TREATMENT

ARMOUR AND COMPANY
GROCERY PRODUCTS DIVISION
CHICAGO, ILLINOIS

Figure 7

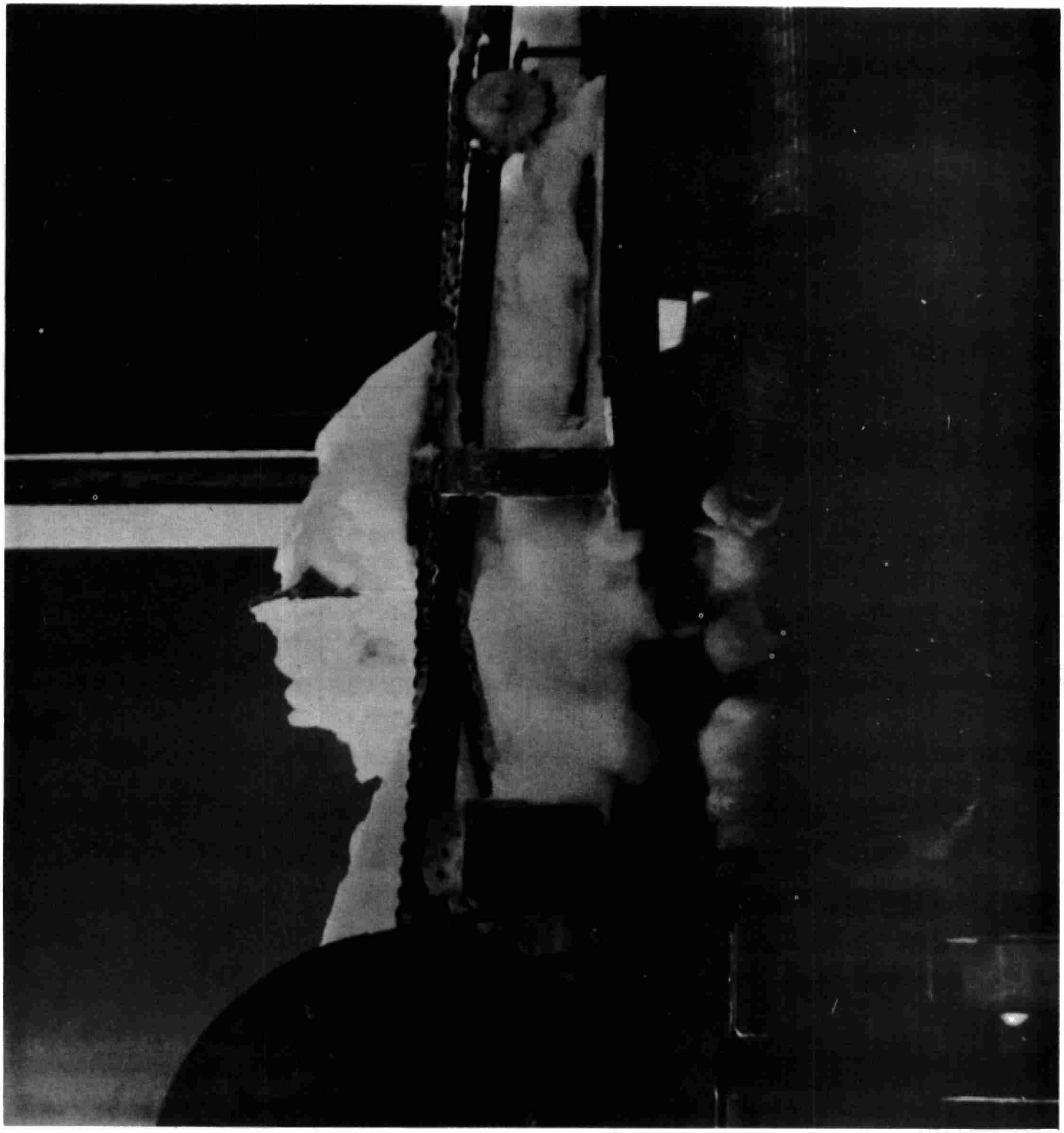
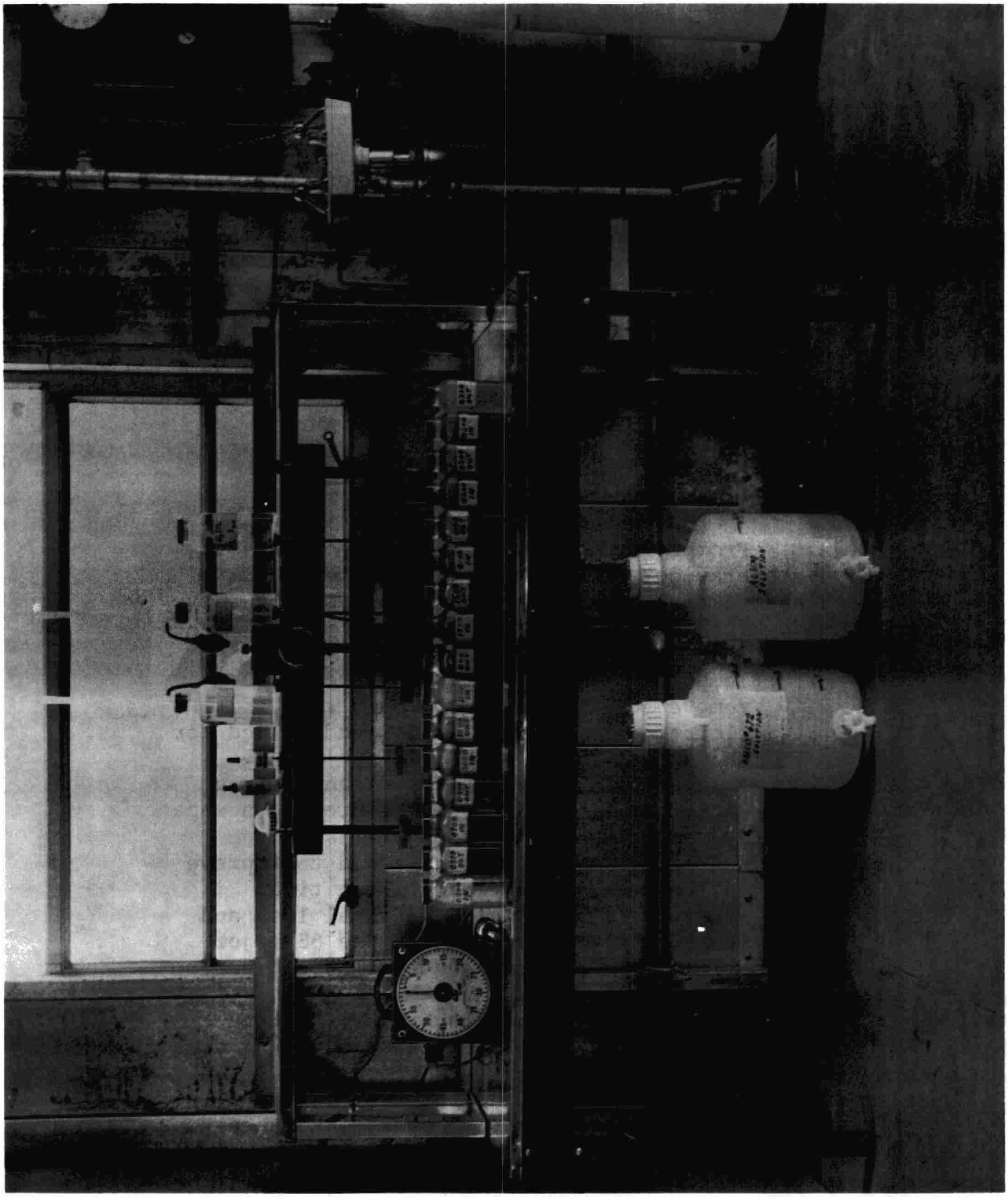


Figure 8

Figure 9

Figure 10



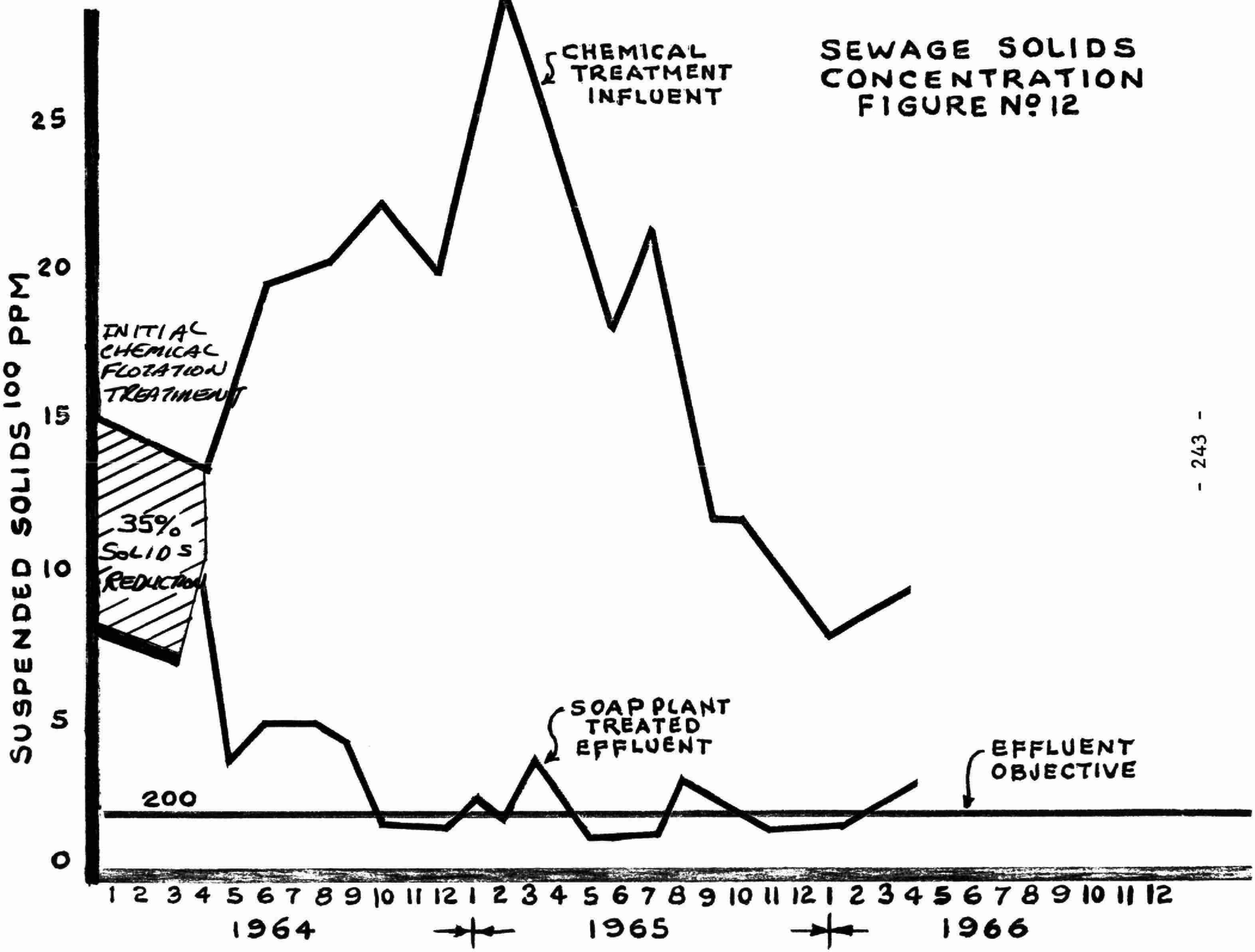
Jar tests were run during this period several times a day to balance the most desirable pH with the use of alum and lime to obtain best treatment results. Our Quality Control people assisted in this operation since they were best qualified and had convenient work areas.

During the first four months of chemical flotation treatment operations, solids removal averaged 35%. (Figure 12) Influent solids concentrations were 1400 ppm; effluent concentrations 900 ppm. Sewage flows averaged 500,000 gallons per day, three times the design capacity of 150,000. This was a training and learning period for operators, supervisors, and engineers. Treatment was soon to become much more effective.

ENGINEERING TREATMENT SURVEY

Prompt organized effort was necessary to improve operations and to summarize and coordinate the treatment problems at hand. An engineering survey was made with the following results:

1. Temporary lagoons were constructed to remove solids passing through the flotation unit since it was undersized for the actual fluid flows.
2. A substantial quantity of clean cooling water was diverted from the process sewage system to existing storm drains.
3. A flocculating agent was added to improve action and reduce flocculation time.
4. A survey of sources of material loss and sewage contamination developed 68 major points for careful operating inspection or mechanical attention.
5. Sewage sampling and laboratory testing were organized to establish control.
6. PH control devices were improved.
7. Pumps for sludge and for chemical addition were improved, so that operating ranges were adequate and equipment reliable.


SEWAGE SOLIDS
CONCENTRATION
FIGURE Nº 12
CHEMICAL
TREATMENT
INFLUENT
INITIAL
CHEMICAL
FLOTATION
TREATMENT
35%
SOLIDS
REDUCTION
SOAP PLANT
TREATED
EFFLUENT
EFFLUENT
OBJECTIVE
200
SUSPENDED SOLIDS 100 PPM
0
5
10
15
20
25
1 2 3 4 5 6 7 8 9 10 11 12 1 2 3 4 5 6 7 8 9 10 11 12 1 2 3 4 5 6 7 8 9 10 11 12
1964
1965
1966

8. Orifice plates were installed at several intermittent loading locations so chemical treatment facilities could keep up with these peak loads.

Treating three times the design quantity of sewage flow resulted in precipitation in the sewers during the half hour required for the plant's effluent to flow to the Aurora Sanitary District treatment plant.

The use of lagoons is a common solution for many treatment problems (Figure 14). In this instance three temporary lagoons were put into operation promptly. The heavy solids loading to the Aurora Sanitary District treatment plant was reduced. Lagoon service was alternated to permit machine cleaning, expensive, but an adequate short-range solution.

In spite of increasing influent solids concentrations to 2,000 ppm, acceptance of the treatment survey recommendations resulted in 70% solids removals to effluent concentration of 500 ppm.

Reassignment of an energetic supervisor resulted in further systematizing procedures (Figure 15). These refinements reduced effluent solids concentrations from 500 to 160 ppm representing 92% removal, the first truly acceptable treatment results.

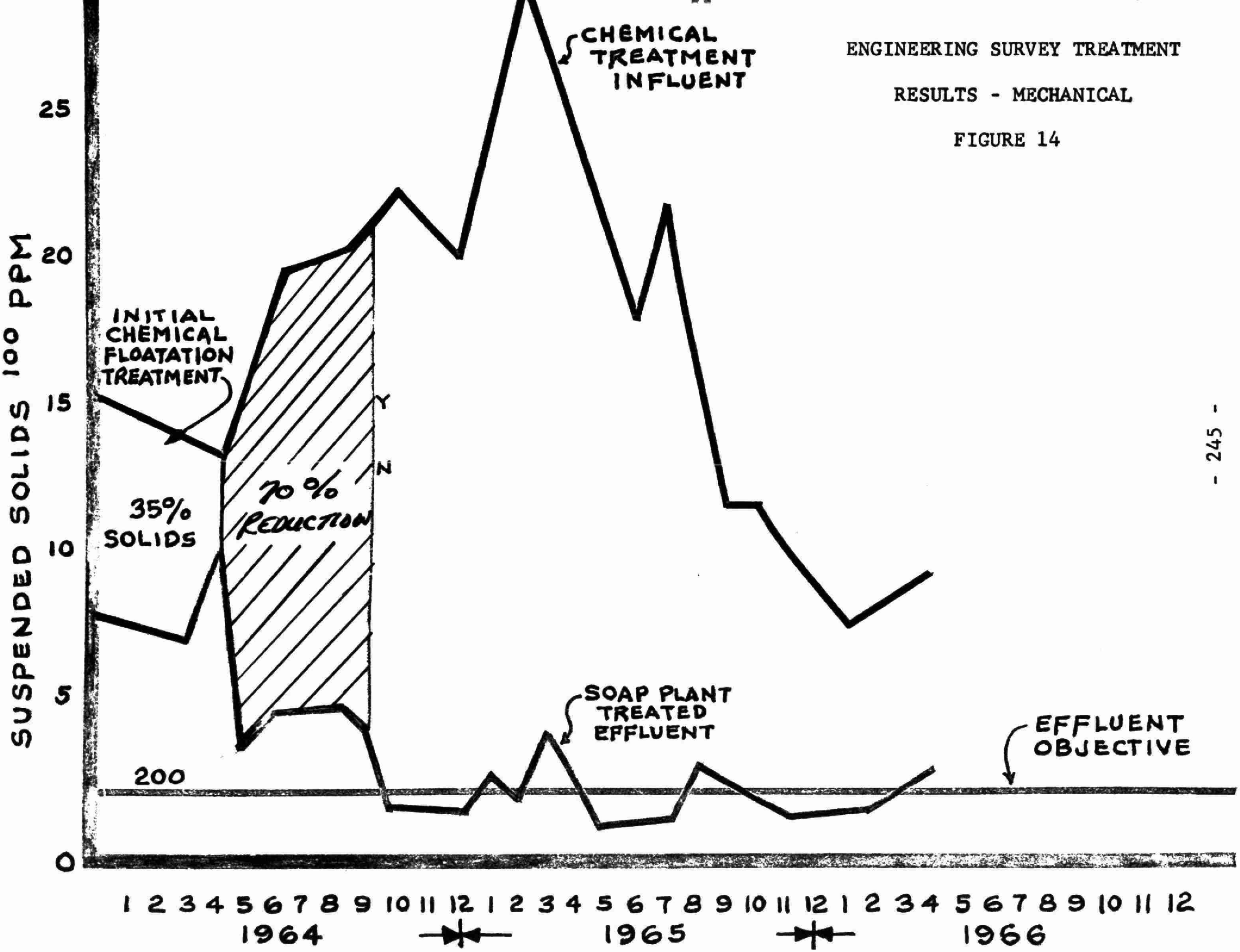
MODERNIZATION PROGRAM

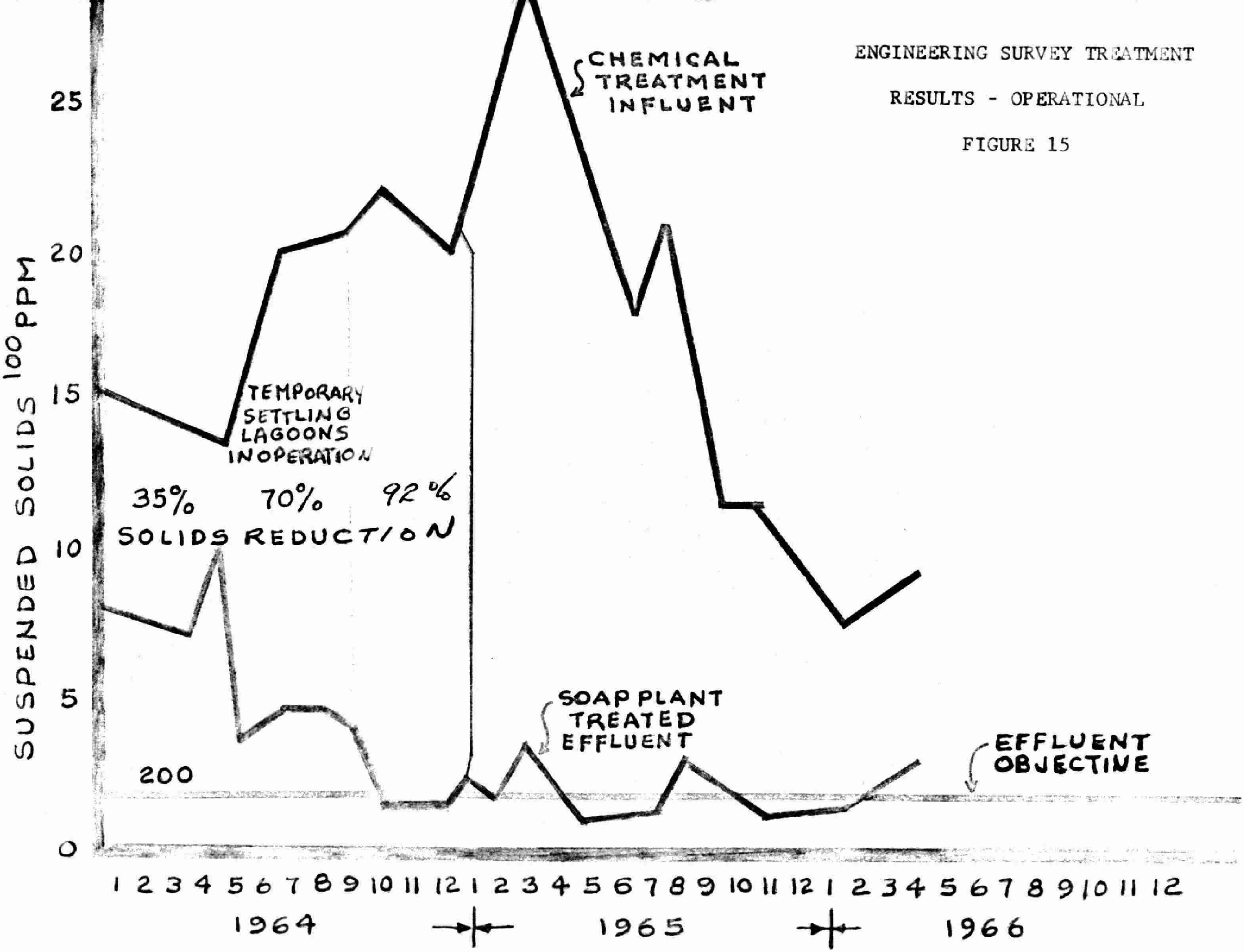
An engineering survey for the long range and permanent solution to this sewage treatment condition resulted in the recommendation that a new chemical treatment plant be constructed to accept 100% of the existing sewage load. The present flotation system would then be on a standby condition and dismantled when the new facility was operating smoothly.

ENGINEERING SURVEY TREATMENT

RESULTS - MECHANICAL

FIGURE 14





ENGINEERING SURVEY TREATMENT

RESULTS - OPERATIONAL

FIGURE 15

FAT SKIMMERS

Approximately one-third of the sewage flow develops from an outdoor continuous raw material fat processing unit (Figure 16). Two major skimming devices were installed to collect fatty materials discharged in this sewage. A trench system, easily inspected and cleaned, connects paved areas and drainage systems. The skimmers are conveniently located for frequent inspection and cleaning. Operating people and supervisors can readily see the nature and quantity of materials being collected from their operation.

These skimmers reclaim major quantities of fatty materials which previously had been chemically treated and dumped for disposal (Figure 17). Now, with the skimmers, fatty materials are reclaimed. Chemical use is reduced, as are sewage sludge quantities for disposal.

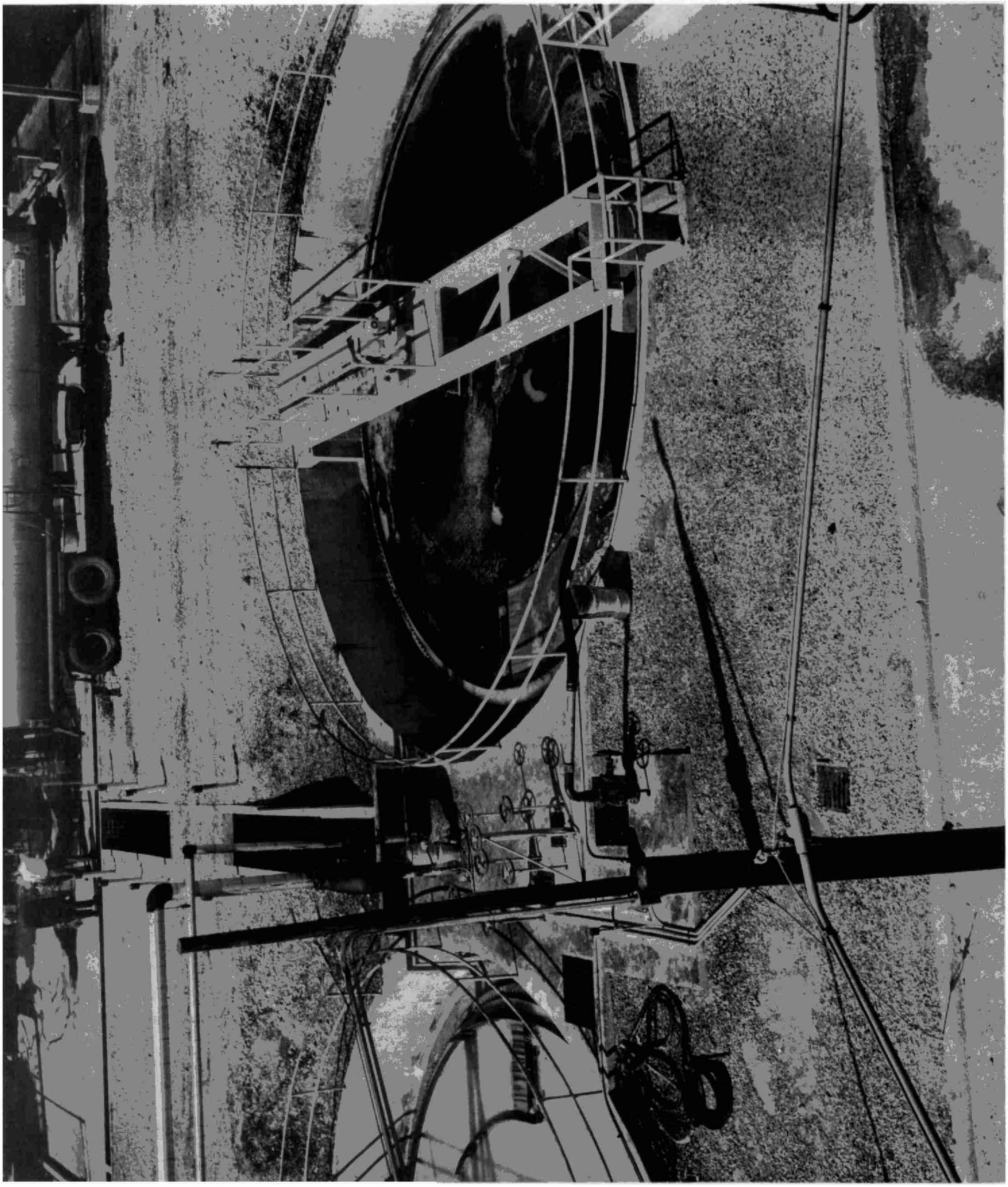
BIOLOGICAL REDUCTION

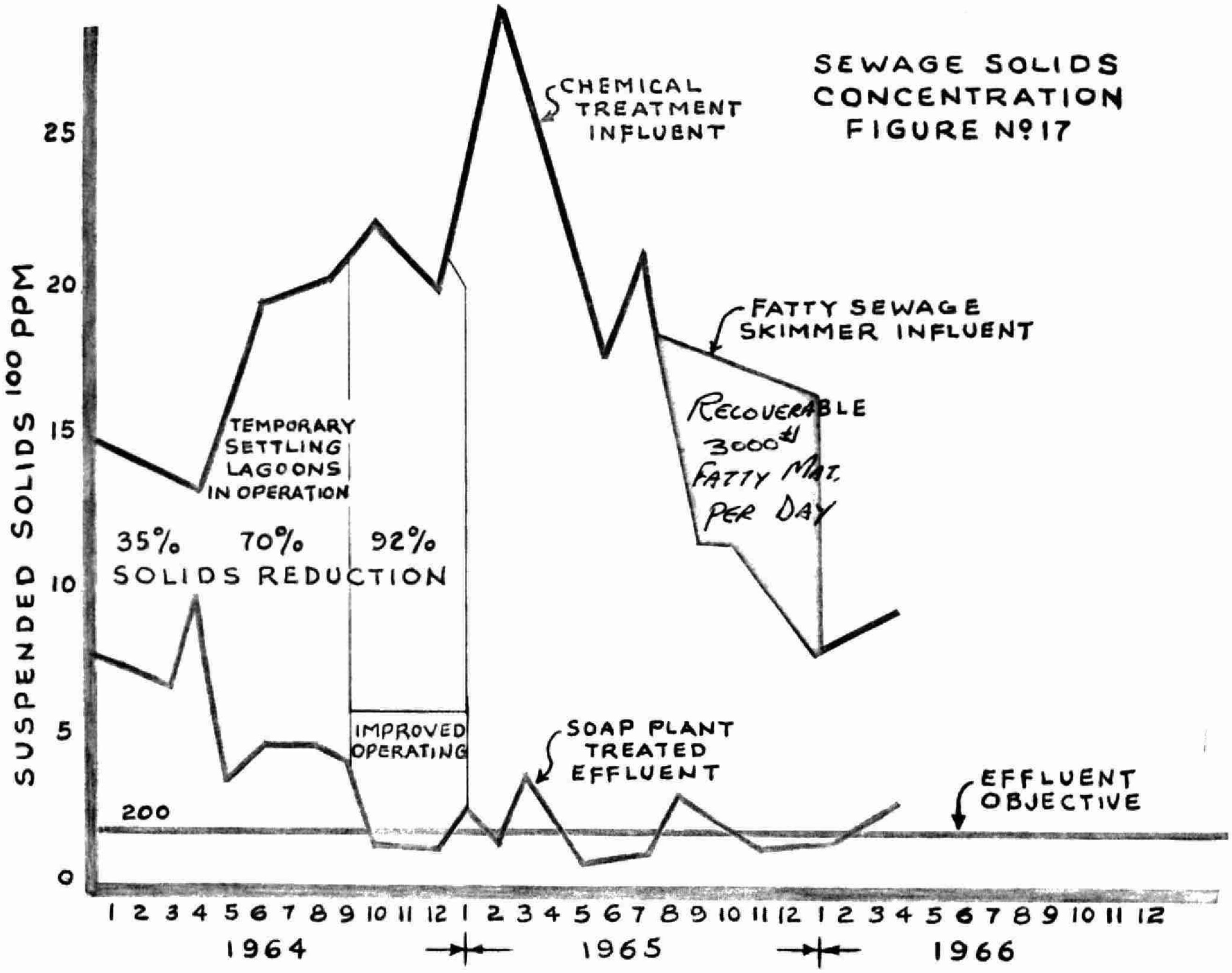
Dissolved contaminants continue to be a major part of the biological sewage load. Improvements in operating procedures and the installation of several process modifications have resulted in a major reduction of the dissolved load by approximately 25% (Figure 18 & 19). However, biological reduction at the plant site became essential.

Hydroscience, Inc., of Leonia, New Jersey, under the direction of John L. Mancini, performed a process design study.

The design of biological treatment systems for individual wastes presents the engineer with the problem of selecting an economical and properly sized treatment system. Among the alternatives are activated sludge, either conventional or high rate, extended aeration with associated aerobic digestion of sludge, aerated lagoons and trickling filters. In many, if not most, instances of treatment of

Figure 16




SEWAGE SOLIDS CONCENTRATION
FIGURE Nº 17
SUSPENDED SOLIDS 100 PPM
CHEMICAL TREATMENT INFLUENT
FATTY SEWAGE SKIMMER INFLUENT
TEMPORARY SETTLING LAGOONS IN OPERATION
RECOVERABLE 3000# FATTY MAT. PER DAY
35% 70% 92%
SOLIDS REDUCTION
IMPROVED OPERATING
SOAP PLANT TREATED EFFLUENT
EFFLUENT OBJECTIVE
200
0 5 10 15 20 25
1 2 3 4 5 6 7 8 9 10 11 12 1 2 3 4 5 6 7 8 9 10 11 12 1 2 3 4 5 6 7 8 9 10 11 12
1964 1965 1966

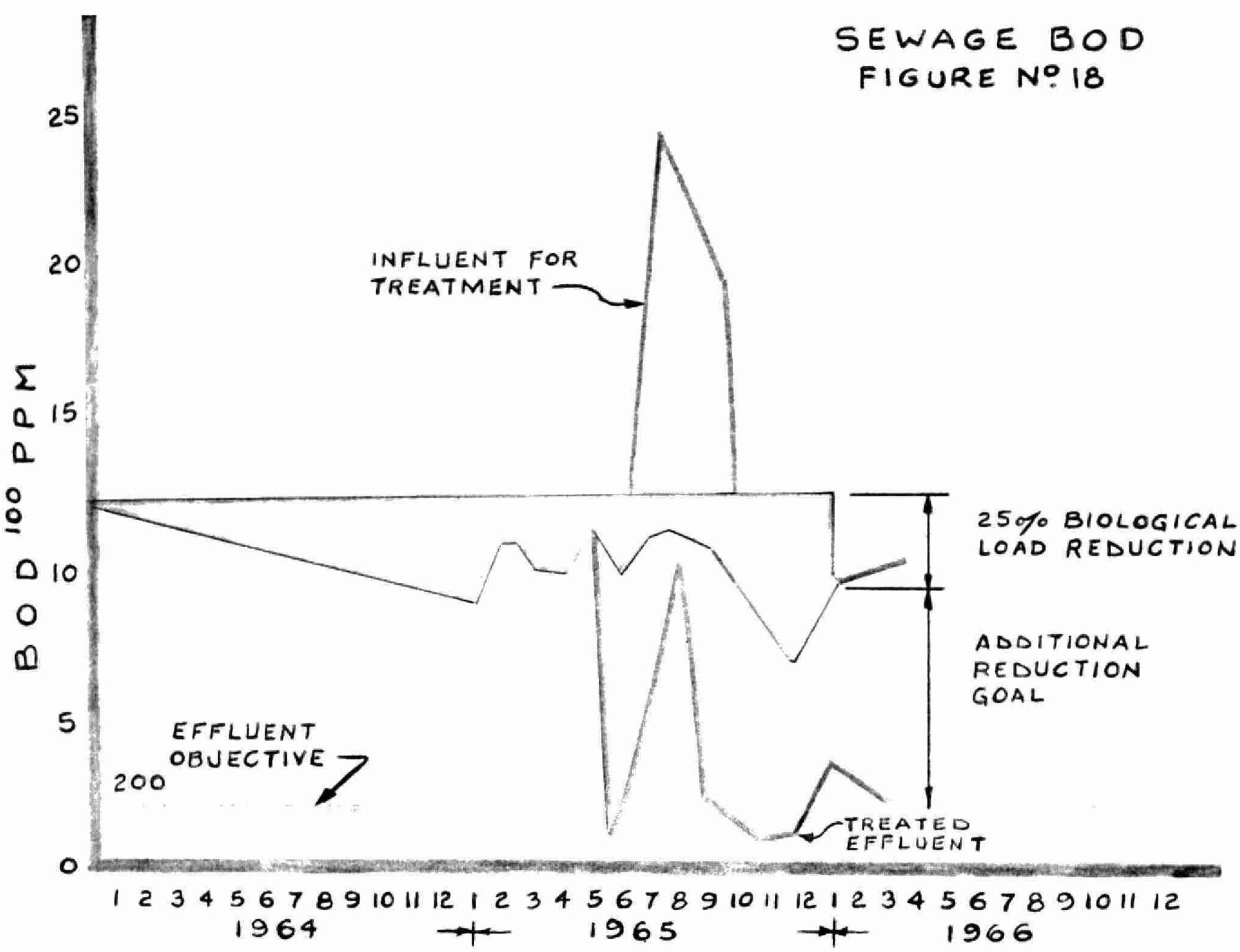

SEWAGE BOD
FIGURE Nº 18
BOD 100 PPM
INFLUENT FOR TREATMENT
25% BIOLOGICAL LOAD REDUCTION
ADDITIONAL REDUCTION GOAL
EFFLUENT OBJECTIVE
200
TREATED EFFLUENT
0 5 10 15 20 25
1 2 3 4 5 6 7 8 9 10 11 12 1 2 3 4 5 6 7 8 9 10 11 12 1 2 3 4 5 6 7 8 9 10 11 12
1964 1965 1966

Figure 19

industrial wastes, it is desirable to conduct laboratory experiments and perhaps pilot scale studies to select the most effective and economical treatment system and to size the facilities properly.

THEORY OF BIOLOGICAL TREATMENT

Biological waste treatment essentially consists of controlling environmental factors to enable a mixed culture of micro-organisms to employ the organic matter in the waste as a food source for reproduction (synthesis) and energy. In the activated sludge and aerated lagoon treatment systems, organisms are suspended in the liquid medium along with the waste to be treated. The culture is aerobic, requiring dissolved oxygen for respiration. Sufficient time is allowed for the organisms to utilize the organics as a food source. In activated sludge treatment, the mixture of treated waste water and organisms is separated. The treated waste is discharged and the organisms are returned to the aeration tank for mixing with incoming waste. In aerated lagoons, organisms are wasted in the effluent at a rate proportional to the gross reproduction (synthesis) rate.

LABORATORY BIOLOGICAL REDUCTION PROCEDURE

The laboratory study described herein was designed to provide information on alternative methods of biological treatment for a particular waste. Multiple biological treatment systems were run simultaneously over a period of approximately twenty days. Each system was operated independently and pertinent variables were analyzed. It was, therefore, necessary to interpolate and develop performance predictions for a one day lagoon system from a laboratory program already completed. Further, influent strength of the waste was to be altered by changes in the manufacturing process. Figures 20 and 21 present the operating results from the one day lagoon with the data obtained in the laboratory study.

FIGURE 20

FILTERED EFFLUENT COD Vs. COD REMOVAL RATE

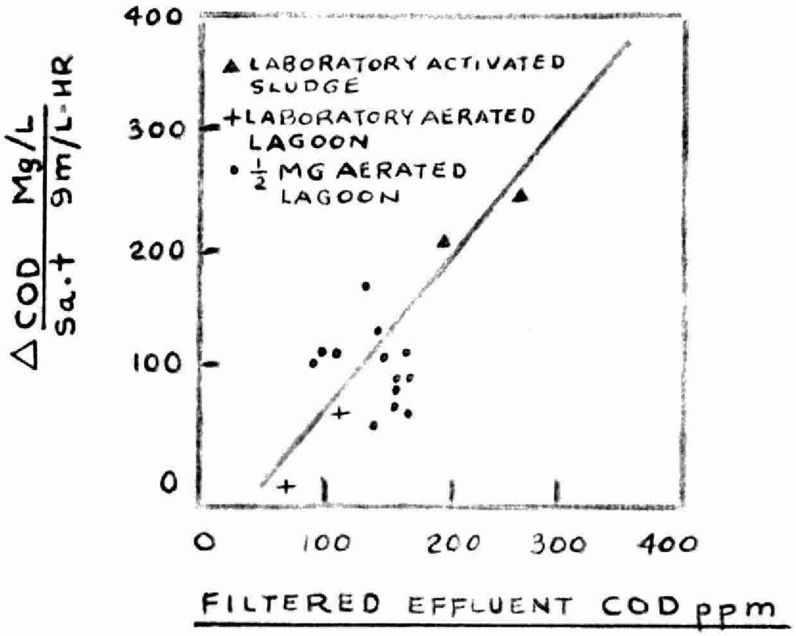
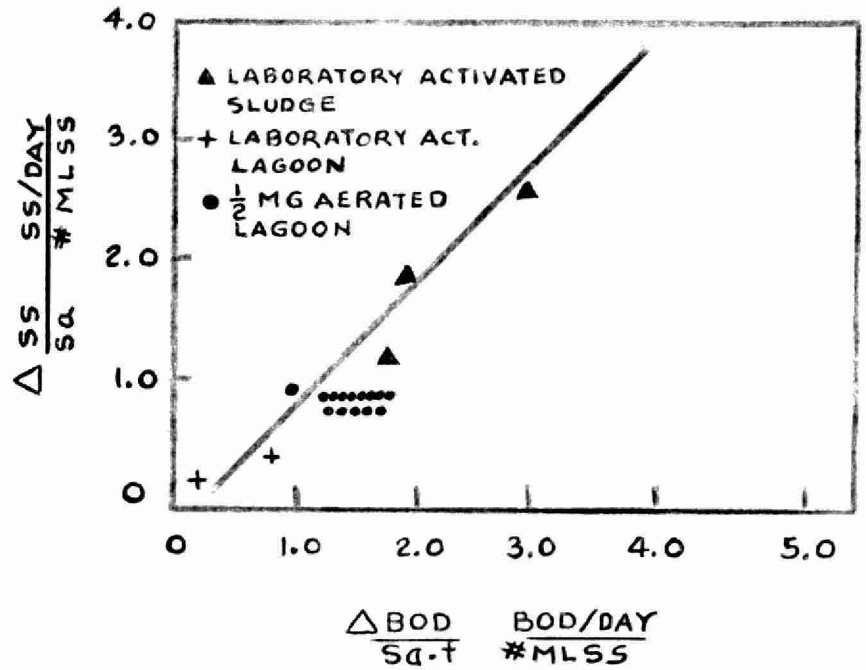


FIGURE 21

SUSPENDED SOLIDS PRODUCTION AS A FUNCTION OF BOD REMOVAL



The scatter of performance data was a result of wide day to day variations in loading. In general, the predicted performance on the effluent was comparable. The results of this study have been discussed at the Water Pollution Control Federation meeting in Atlantic City, New Jersey, in October, 1965 by Messrs. Mancini and Barnhart.

ARMOUR'S AURORA BIOLOGICAL SYSTEM

The biological system consists of four lagoons, one of which is aerated (Figures 24 & 28). Two lagoons are for solids settling.

Influent operating loads have been steadily reduced, approaching 25% as noted earlier (Figure 25).

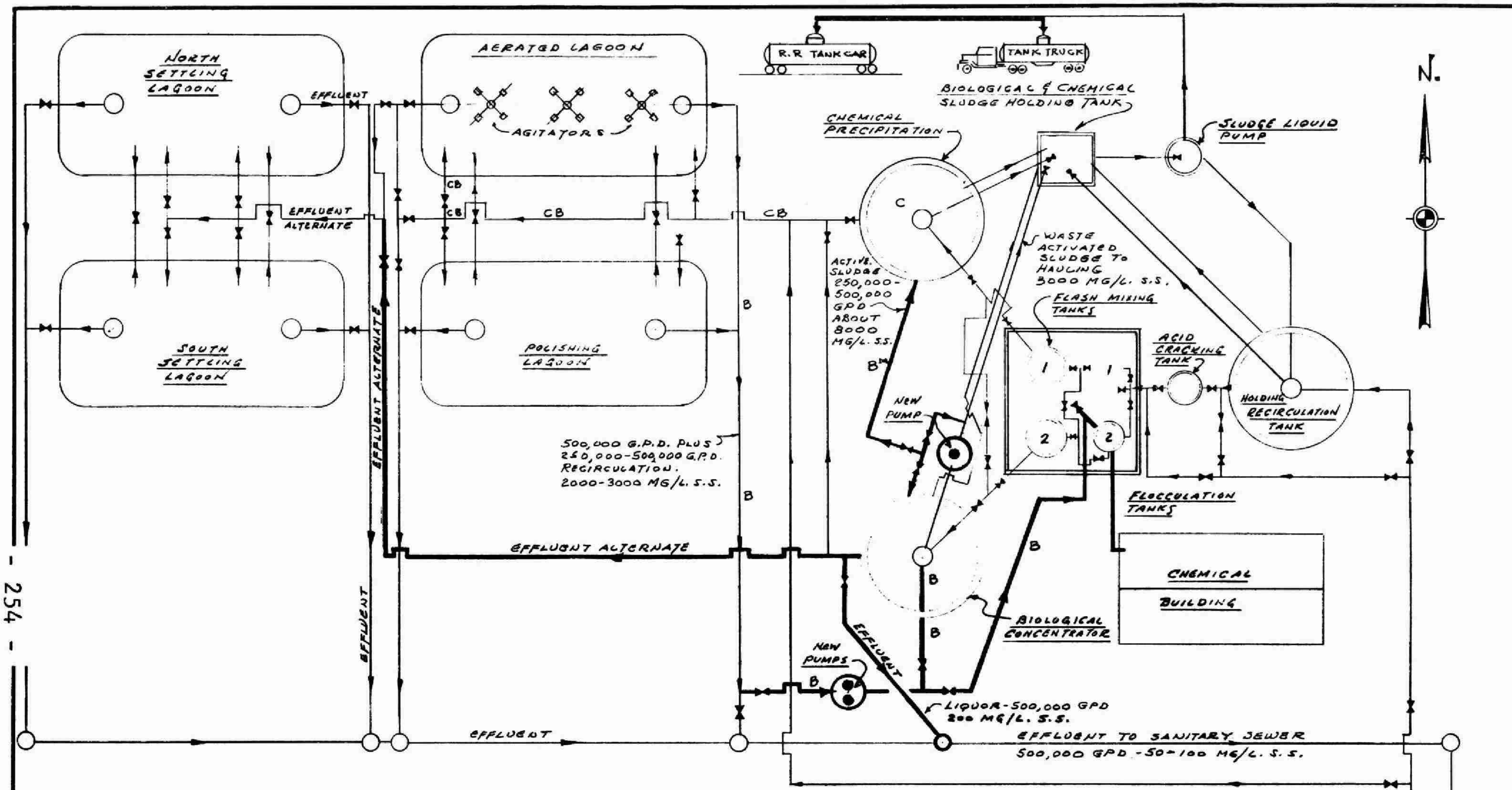
The aeration system has operated in excess of its design conditions for most of its experience. It is most productive during summer months when lagoon operating temperatures are above 80 degrees F. Almost no attention is required to maintain optimum conditions.

Armour Agricultural Chemical Company, a Division of Armour and Company, produces and markets a wide number of fertilizers. Since nitrogen and phosphorus are chemical elements common to both fertilizers and sewage nutrients, this Armour Division maintains a Technical Service Administrator in the company's Atlanta, Georgia, office to advise and service customers requiring nutrients.

Arm-Bac is the trade name for these nutrients which can be proportioned specifically to each customer's requirements and provided in solid or liquid form.

At Aurora, tank truck quantities of liquid nutrient are trucked from the nearest mixing-supply station located in Belmond, Iowa. Daily requirements of 600 pounds of liquid are metered to provide the following chemical quantities:

Nitrogen - 115 pounds Phosphorus - 25 pounds



ALTERNATE OPERATING SCHEMES

1. BIOLOGICAL CONCENTRATOR EFFLUENT DISCHARGE TO ASD WITHIN CONTRACT LIMITS.
2. IF REQUIRED, CHEMICALS CAN BE ADDED TO IMPROVE EFFECTIVENESS OF BIOLOGICAL CONCENTRATOR.
3. BIOLOGICAL CONCENTRATOR EFFLUENT CAN FLOW THROUGH SOLIDS SETTLING LAGOON AS AN INSURANCE MEASURE TO CONTROL EFFLUENT
4. ALTERNATE USE OF POLISHING LAGOON IS TO SETTLE BIOLOGICAL SOLIDS PRIOR TO BIOLOGICAL CONCENTRATOR, OR POLISHING LAGOON CAN BE USED TO SETTLE CHEMICAL & BIOLOGICAL SOLIDS PRIOR TO AERATED LAGOON.
5. REVERT TO PRESENT OPERATIONS USING 2 CLARIFIERS IN CHEMICAL PRECIPITATION SERVICE AND SETTLING LAGOONS TO REMOVE BIOLOGICAL SOLIDS.

— LEGEND —

"B"-BIOLOGICAL SLUDGE
"C"-CHEM. PRECIPITATED EFFLUENT
"CB" MIXTURE OF CHEM. EFF. & BIO. SLUDGE

REF. WARREN & VAN PRAAG INC. FLOW SHEET DATED APRIL 1966

REVISION	APPROVAL	DATE

ARMOUR GROCERY PRODUCTS CO.
DIVISION OF ARMOUR & COMPANY

PLANT AURORA DEPT.

BIOLOGICAL CONCENTRATOR CLARIFIER PIPING MODIFICATIONS FLOW SHEET

C & R- A-65

SECTION

ENGINEERING DEPT.

DRAWN A.C. DATE 5-4-66

CHECKED SCALE NONE

DRAWING NO. A-ST-4 REV.

Figure 24

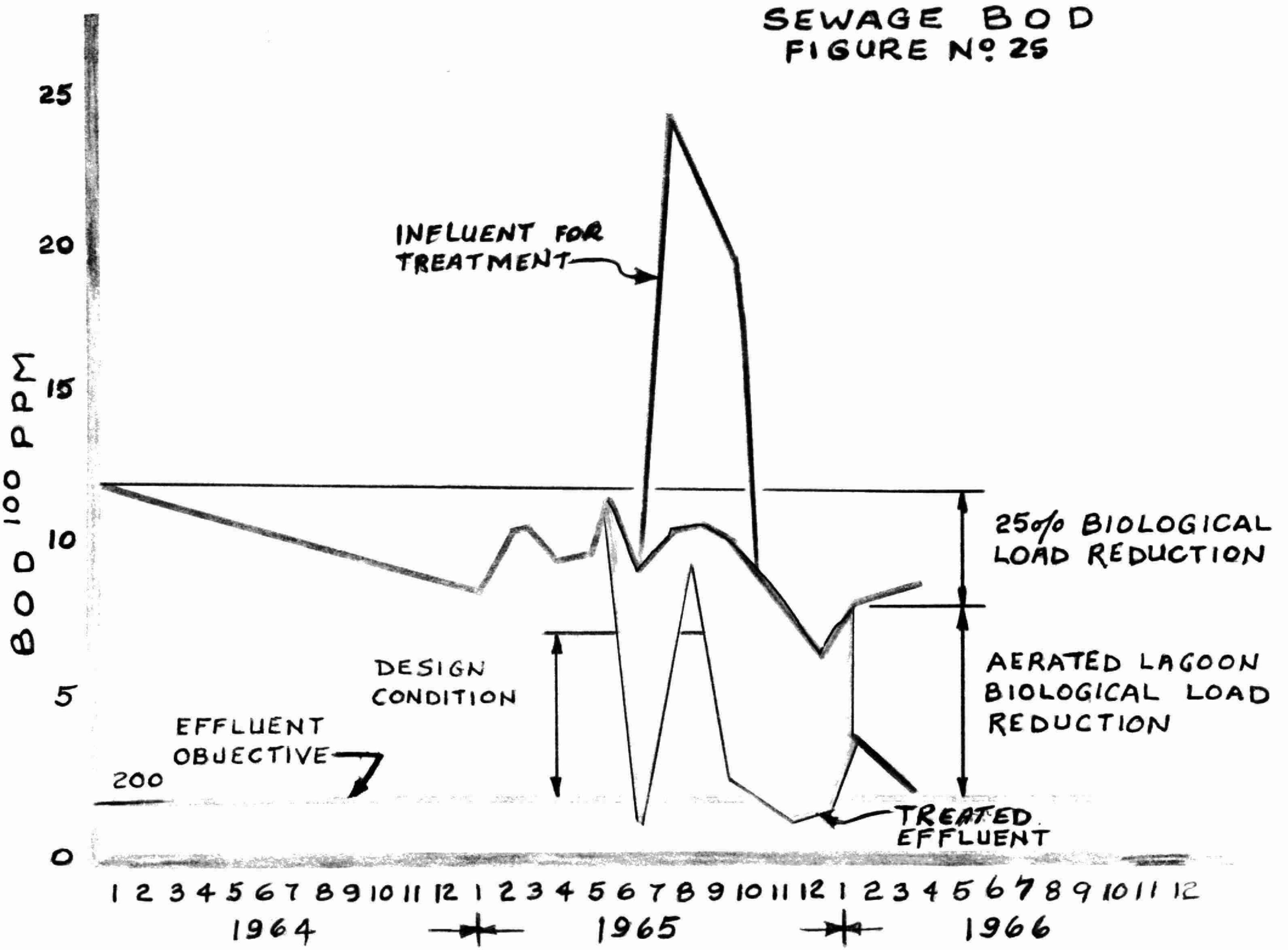
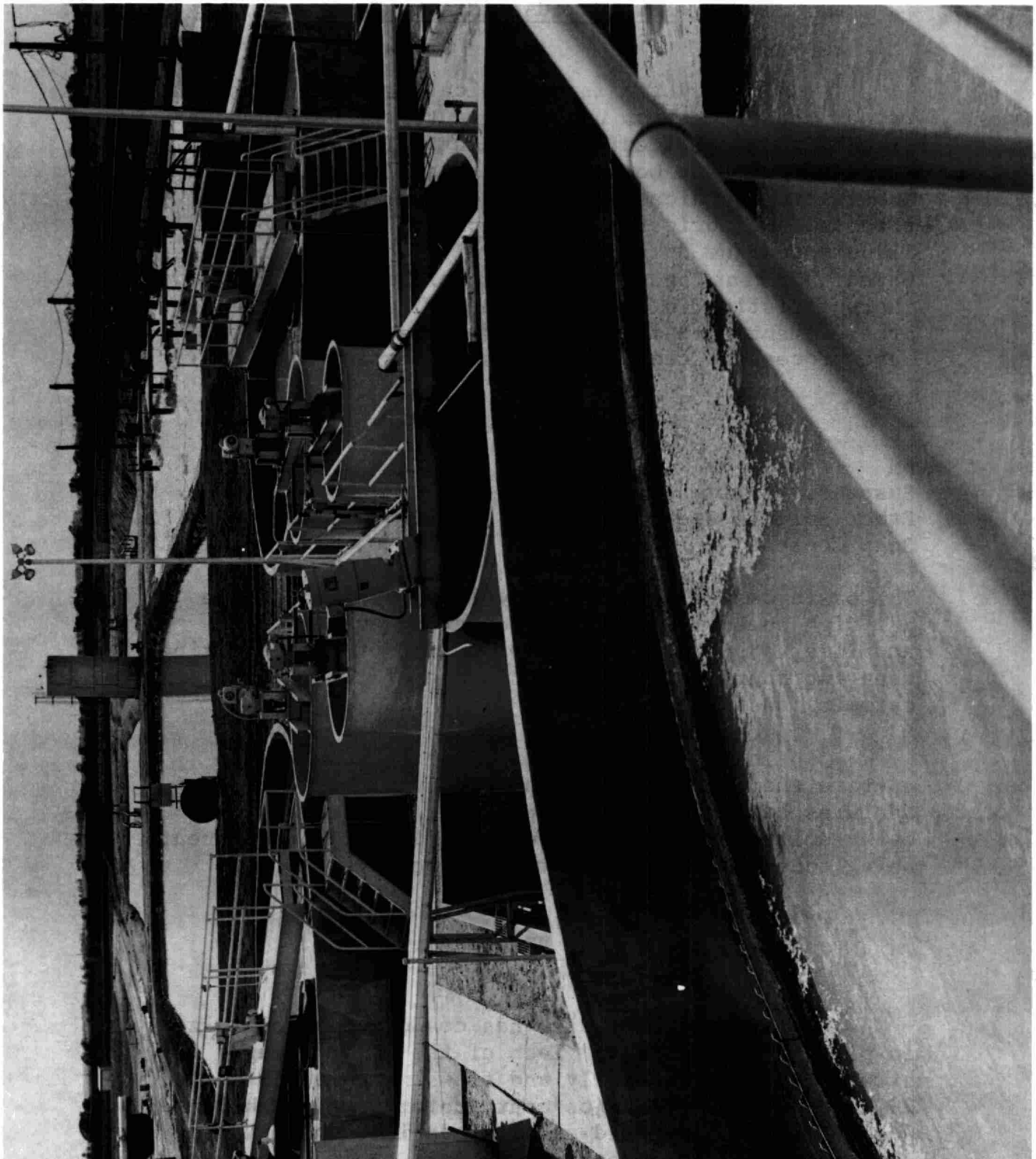

SEWAGE BOD
FIGURE No. 25
25
20
15
10
5
0
BOD 100 PPM
INFLUENT FOR TREATMENT
25% BIOLOGICAL LOAD REDUCTION
DESIGN CONDITION
AERATED LAGOON BIOLOGICAL LOAD REDUCTION
EFFLUENT OBJECTIVE
200
TREATED EFFLUENT
1 2 3 4 5 6 7 8 9 10 11 12 1 2 3 4 5 6 7 8 9 10 11 12 1 2 3 4 5 6 7 8 9 10 11 12
1964
1965
1966

Figure 28



NEW CHEMICAL TREATMENT

This system is a chemical precipitation rather than flotation unit with automatic devices and standby chemical feeding equipment. The Walker Process Equipment Company of Aurora, Illinois, now a subsidiary of Chicago Bridge and Iron, designed the process and fabricated the equipment. This table illustrates the criteria upon which designs will be based. Current operations will seldom result in characteristics in excess of these limits. Waste pretreatment equipment suppliers were requested to base process guarantees upon these characteristics.

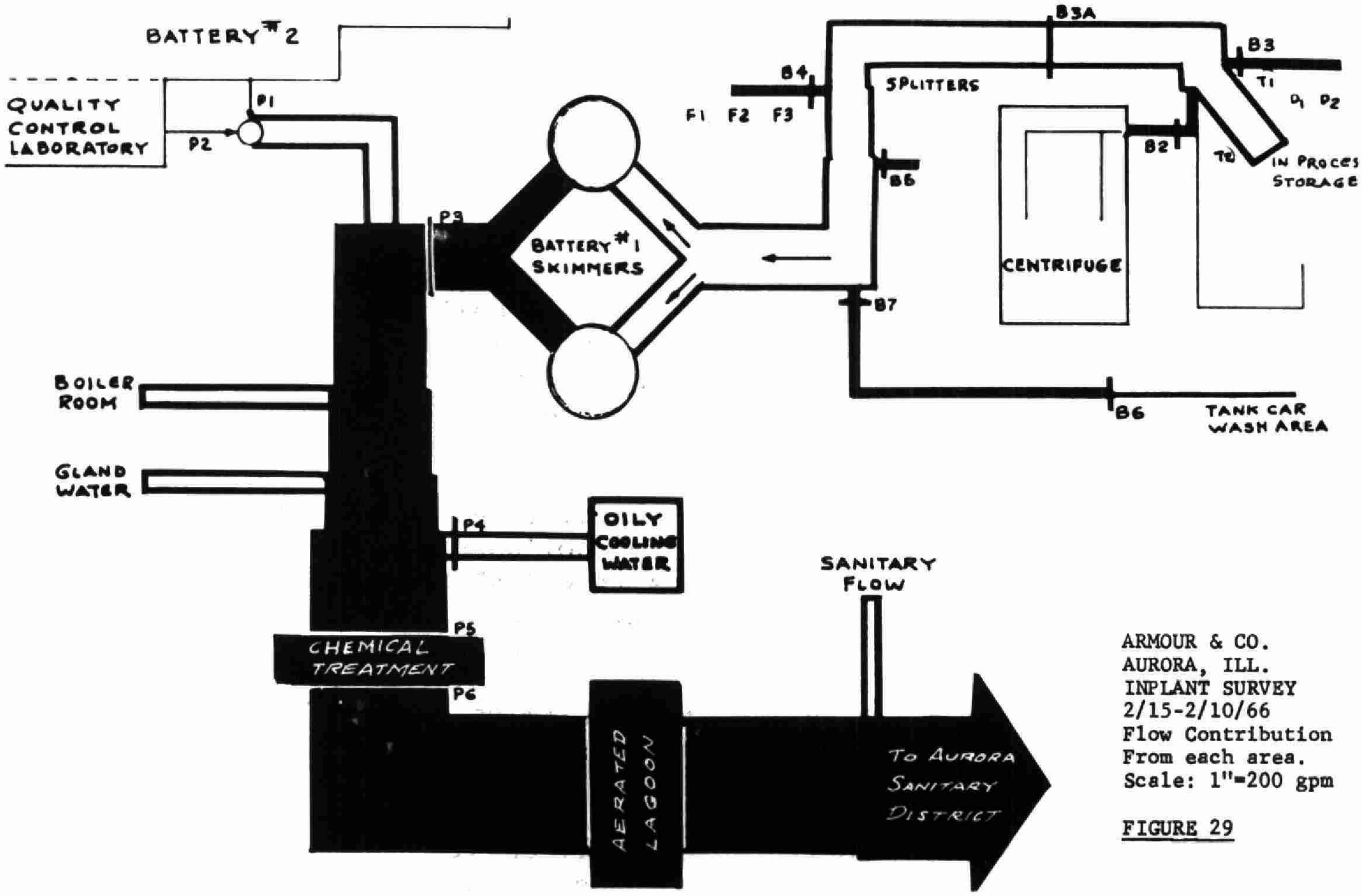
	Low	High
pH	6.2	13.0
Suspended Solids (p.p.m.)	50	6000
Ether Soluble Grease (p.p.m.)	50	6000
Soap Content	Neg.	2%

The basic design principle involves lowering of the pH, high speed mixing of flocculating agents, alum and lime, a short flocculation period of gentle mixing, then two hours settling time in one of two major skimming basins.

The new facility has been much easier to operate and incorporates many improved design features based on actual experience (Figure 28). It has resulted in generally improved quality of effluent being accepted by the aeration lagoon system.

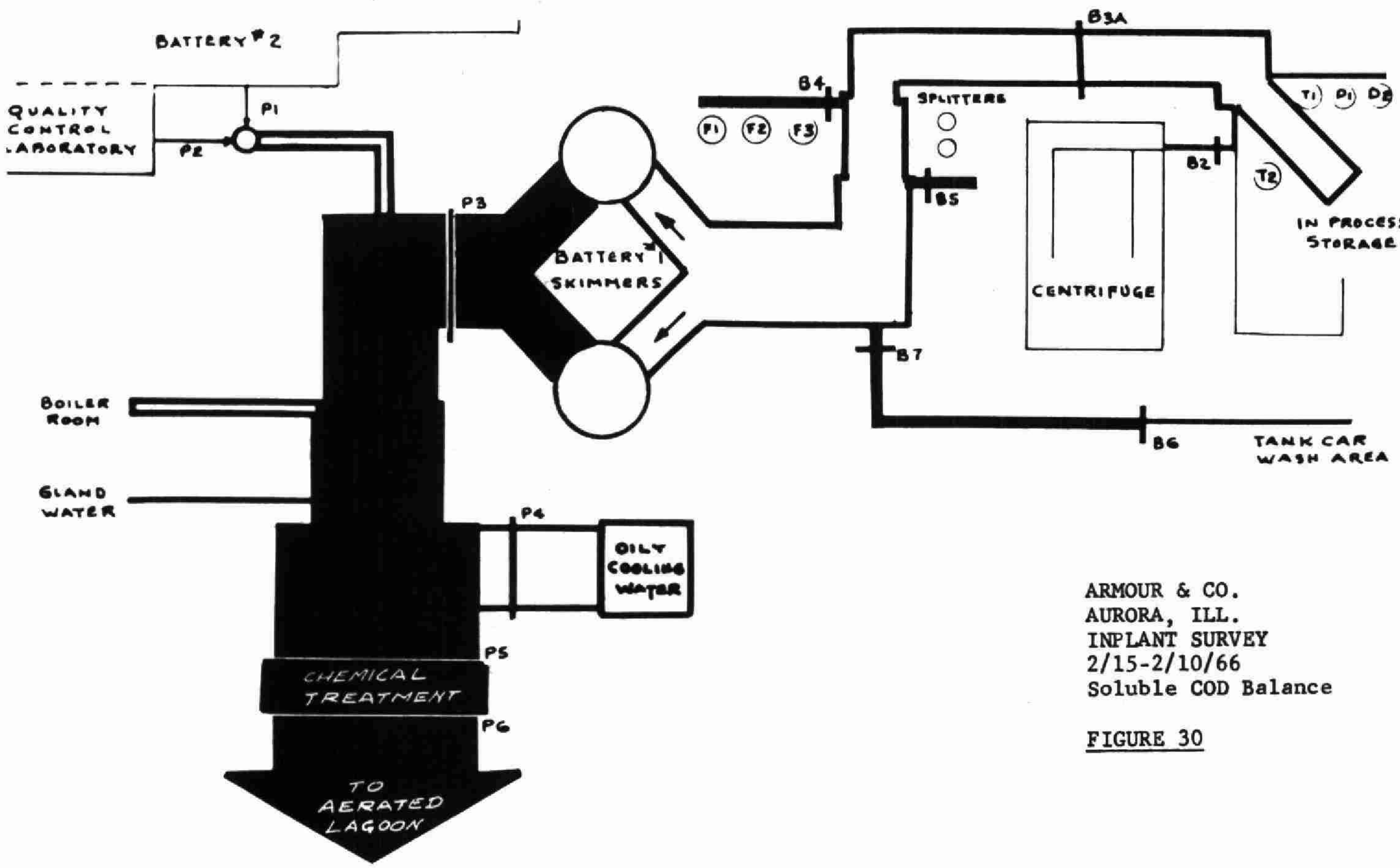
IN-PLANT STREAM SURVEY

Hydroscience also has conducted an organized in-plant stream survey. Each of the major sewage streams is sampled hourly and flows measured (Figures 29 & 30). Once the major contributors are established, additional concentrated sampling defines the frequency and cycling of load characteristics. This survey has resulted in concentrating on certain operating procedures and improving process equipment so that loads requiring treatment have been reduced.



ARMOUR & CO.
AURORA, ILL.
INPLANT SURVEY
2/15-2/10/66
Flow Contribution
From each area.
Scale: 1"=200 gpm

FIGURE 29



ARMOUR & CO.
AURORA, ILL.
INPLANT SURVEY
2/15-2/10/66
Soluble COD Balance

FIGURE 30

SLUDGE DISPOSAL

Major quantities of sewage sludges result from sewage treatment plants. It is becoming more and more difficult to dispose of these materials in lagoons or land fills. Resulting odours or contamination are risks incurred when sludges require disposal.

Armour's long range objective at Aurora is to provide on-site facilities for solids digestion. Hydroscience, Inc. continues as technical consultants to participate in process selection. Considered in this study phase are: (a) Stabilization, dewatering and disposal of the combined sludges (biological, chemical, and oily cooling water skimmings), and (b) separate handling and disposal of the individual sludges.

For the short range, until on-site facilities can be designed and constructed, an improved sludge disposal area is required. A wide ranging survey, substantiated by soil boring in two locations, has located a site geologically suitable for a natural, sealed reservoir. Final consent of all concerned for a controlled disposal operation is expected shortly. Railroad transportation of liquid wastes to this remote location will reduce costs and insure all-weather access.

BIOLOGICAL SOLIDS CONCENTRATION

One of the concentrators now on final chemical treatment service will be repiped shortly and placed in service to concentrate biological solids, thus replacing two existing settling lagoons which are temperamental and major sources of summertime odours.

Recirculation of biological solids will reduce their volume through digestion, improve settling characteristics and stability.

OF SPECIAL INTEREST

Sanitary Districts

Well managed Sanitary Districts can operate in a flexible and cooperative atmosphere to encourage industrial expansion within a community.

The Aurora Sanitary District offers such management with a three member Board of Trustees of experienced community-minded businessmen: Chairman J.C. Esnorff, Messrs. D.R. Stein, F.P. Adams, Attorney W.H. Wake and Engineer W.E. Deuchler.

The former attorney for the Aurora Sanitary District, R.E. Dolph, has assisted the District to develop legal precedents to obtain critically necessary expansion funds in the face of negative referendums.

Aurora Sanitary District Plant Superintendents have gained wide reputations. W.A. Sperry was with the plant for years and is now retired in the community. Williard Pfeifer is providing outstanding leadership as his successor.

The Walker Process Equipment Company, now a subsidiary of Chicago Bridge and Iron, is a local industry, specializing in the design and construction of sewage process treatment equipment. They have provided all of the major treatment devices with the exception of the aerators.

Also, we of the State of Illinois, are privileged to enjoy the leadership of Clarence Klassen of the State Sanitary Water Board and Ben Leland of the State Sanitary Water Board of the Chicago District.

Sewage Loads Reduction

A wise businessman will reduce material and process losses. In doing this he will have more material for his product and less losses requiring expensive sewage treatment. Thus, a pound of material saved is the source of two cost advantages.

Solids Disposal

Major sewage treatment facilities must result in accumulating sewage solids which require disposal. This can be a major planning and financial problem.

Inspection

Planning facilities, so that people responsible for actions can see the results, is an important design aspect (Figures 32 & 10). The locations of the skimmers, the use of open-top trenches, and the hourly bottle samples of influent and effluent are examples.

Material Samples

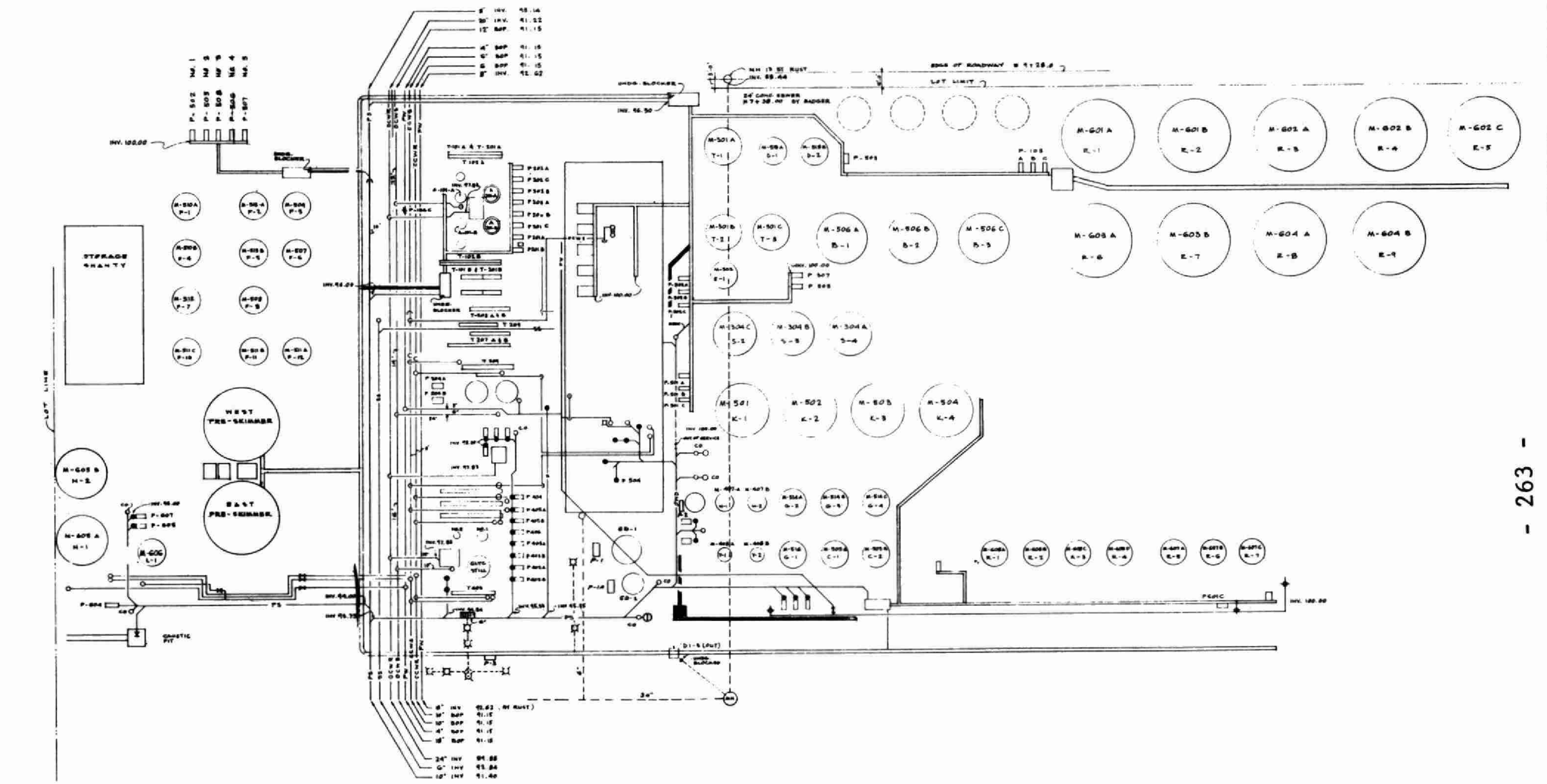
The best design is obtained when actual samples of materials are available for analysis. With industrial sewage plants this may mean that facilities are designed and constructed on a step-by-step basis, planning the next facilities only after the previous one is in operation and is consistently performing in a satisfactory manner.

Schedule

Such a design procedure requires extreme control and patience during the learning and startup period. It may be impractical during these times when extreme pressure is being exerted from many sources to alleviate polluting conditions. However, to hurry into a design and construction commitment, then find the facility will not perform as needed, will not save time and will not result in the most expedient solution.

Odours

Sewage treatment facilities, particularly when long detention time is involved, can result in the generation of odours which may be disagreeable to the plant employees and neighbours. These odours can be controlled with the proper procedure and materials but this is not always economical or simple.



LEGEND :

OWD	OIL-WATER DRAIN
PS	PROCESS SEWER
SS	SANITARY SEWER
OCWR	OILY COOLING WATER RETURN
OCWS	OILY COOLING WATER SUPPLY
DW	DOMESTIC WATER
PW	PLANT WATER
CCWS	CLEAN COOLING WATER SUPPLY
CCWR	CLEAN COOLING WATER RETURN
FW	FIRE WATER
	FLOOR DRAIN
	EQUIPMENT DRAIN
	CONCRETE TRENCH
	FLANGED CONNECTION
CO	CLEAN OUT
DI-6	STORM SEWER DRAIN INLET
MH-14	STORM SEWER MANHOLE
	STORM SEWER
B	BINE (ABANDONED UNDERGROUND)

FIGURE 32

NO.	DATE	BY	REVISION	ISSUED FOR	BY	DATE	APPROVAL	DATE

ARMOUR AND COMPANY
GROCERY PRODUCTS DIVISION
DEPT. ENGINEERING PLANT AURORA

BATTERY I
UNDERGROUND PIPING

C&R-
SECTION

ENGINEERING DEPT.
DRAWN A. K. DATE JAN. 14, 66
CHECKED SCALE

DRAWING NO. A-U-4 REV.

Aerated Lagoons

Aerated lagoons, when applicable, are simple to operate and one of the most economical devices for reducing large biological loads.

CONCLUSION

This experience at the new Aurora Soap plant has been new to all of us, particularly the aspects of sewage treatment reviewed herein. It is just one of several major programs required to maintain this business venture and build public trust.

PANEL DISCUSSION OF EFFLUENT AND RECEIVING WATER QUALITY OBJECTIVES

W. F. FELL
CONTROL SUPERINTENDENT
THE ONTARIO PAPER CO. LTD.

H. R. HOLLAND
SENIOR ENGINEER ASSOCIATE
IMPERIAL OIL ENTERPRISES LTD.

A. A. SCHULDT
ASSISTANT UTILITIES ENGINEER
UTILITIES DEPARTMENT
STEEL COMPANY OF CANADA LTD.

R. H. MILLEST
DIRECTOR, DIVISION OF INDUSTRIAL WASTES
ONTARIO WATER RESOURCES COMMISSION

PANEL DISCUSSION ON EFFLUENT AND RECEIVING WATER QUALITY OBJECTIVES

CONTRIBUTION OF W. F. FELL

In January, 1965, the Ontario Water Resources Commission announced certain objectives for pulp and paper mills in Ontario with regard to their waste discharges.

In order to evaluate the situation as it was then, and to determine the ability of the industry to meet these objectives, a three man task force was set up by the Canadian Pulp and Paper Association to make a study and report through the Association to the Commission. This Task Force was comprised of Mr. H. Banfill of Domtar, Cornwall, Mr. G. Dewart of Abitibi Paper Co., and Mr. W. F. Fell.

To help in this evaluation, we first made a tour of some 16 mills in the United States. These mills were known for their efforts made towards stream improvement. They stretched from Wisconsin and Michigan to Mississippi and Alabama and covered several different types of operation.

Following the visit to the United States, the Task Force visited 42 pulp and paper mills in Ontario to evaluate and report on the conditions then existing and on their plans or ability to reach the objectives set.

A similar Task Force has just completed a further tour of 58 pulp and paper mills in the Province of Quebec.

During the course of these various trips, we had an opportunity to determine the practicability of the objectives themselves.

In general, the concept of objectives is a good one. However, care must be taken that unrealistic pressure does not make them standards which must be met regardless of other considerations. In practice, local and economic factors must be taken into account. We should not overlook the fact that the pulp and paper

mills in Ontario employ some 22,000 people, earning $125,000,000 per year and that woods operations supplying the mills would increase these figures substantially. In many areas, were it not for the mills, there would be no reason for the establishment and growth of a community.

The objectives published included suspended solids set at 50 p.p.m. This is essentially an effluent standard and was designed to prevent long term effects of solids settling out and affecting the bottom of the rivers and lakes. Our opinion of this objective can be expressed in three ways:-

(i) An objective set as a concentration does not take into account widely varying types of operation in industry. It is a reflection of sanitary sewage treatment practice where the "raw material" (so to speak) is relatively constant. In the industry, water usage varies depending upon the process used and upon the extent to which the mill has closed up its system. A mill using 3,000 gallons per ton would have 10 times the concentration of one using 30,000 gallons per ton, for the same amount of waste. Where efforts have been made to lower the amount of waste, in many cases the concentration has gone up. These mills should not be penalized for past efforts.

(ii) The second criticism is on the figure of 50 p.p.m. itself. Paper mill wastes are generally organic in nature, similar to sanitary sewage except that the latter is hazardous to health while the former is not. Primary treatment of sanitary wastes result in concentrations of discharges of perhaps 75 to 100 p.p.m. Published data taken from the Water Pollution Control Federation journal has averaged 100 p.p.m.

Referring to paper mill wastes, the primary treatment of mills visited by the Task Force resulted in effluents of about 75 p.p.m.

Data published in the Journal of the Sanitary Engineering Division, American Society of Civil Engineers, (Dec. 1964) showed that primary treatment in 25 American paper mills resulted in effluents averaging 107 p.p.m. These facts would indicate that the objective set is about one half of what might be expected by established practice.

(iii) The third criticism is related to the second and deals with the ability of many paper mill wastes to settle. There is a distinct difference between filterable and settleable solids. Some materials will not settle in 30 days, let alone in 2 to 4 hours. Equipment designed for in-plant treatment may do a better job of recovery of such material and, at the same time, pay for some of the cost. The fact that this approach has been taken in many places led to the phrasing "primary treatment and/or control" in the OWRC objectives. Unfortunately, some people have the idea that if it pays for itself, it is disqualified as a pollution control measure.

Generally speaking, we feel that, as a concentration, an objective of 100 p.p.m. is more practical although in many cases it will be improved upon. At the same time, an alternative objective for process wastes might be 1-2% of the production. This is similar to the approach used in some American states. Both of these suggestions presupposes a solution to the bark fines problem, which is one that many Canadian mills are confronted with and which is being carefully studied. On the other hand, bark fines are not a problem in many of the mills in the southern states where dry barking can be carried out. Until this problem is solved, a further 1% should be considered acceptable. At this level, no coarse bark would be lost, only the very finest, almost colloidal material.

With regard to dissolved solids and B.O.D., the objective stated was for a minimum dissolved oxygen content of 4.0 p.p.m. in the receiving stream. This approach is good in that working capacities of the streams may be used. Enormous amounts of water are used by industry in Ontario (over 560,000,000 U.S.G. per day by the paper industry alone). In spite of this, the water resources themselves are so great that very few waterways are troubled by dissolved oxygen contents lower than the objective. In most of these, the installation of hydro dams has been the cause of a drop. The flooding of muskeg areas alone can drop the oxygen level below the objective. In other cases removal of rapids can lead to a loss in recovery capacity. In the case of this objective, too, local conditions and needs should be taken into account. The

relative needs can be judged by some of our mills with dilutions of 100/1 or greater, compared to some American mills where the stream is the mill effluent. A river should not require game fish treatment where game fishing is not and never was a factor.

Other items under the objectives set out covered foam, colour and fish taste. In some areas where these might be considered or are suspected to be a problem, research and development are going ahead to evaluate or to reduce the effects. By and large, they are not factors of any great importance.

Most of the mills in Ontario are relatively old, with half being in operation for over 50 years. Space and design have made the reduction in losses difficult. In spite of this, it is expected that, in the seven years ending this year, suspended solids being sewered will have been reduced 56.5% at a cost of over $22,000,000. A further $10,000,000 has been spent in reducing dissolved solids. The co-operative approach which the industry has had with the OWRC has yielded considerable results and can continue to do so.

We feel that this co-operative approach should be continued, using reasonable objectives to aim for and economic considerations to decide the need.

CONTRIBUTION OF H. R. HOLLAND

In the summer of 1833, my great-great uncle rode from London to the mouth of the St. Clair looking for land. His diary describes the magnificent river, teeming with fish and wild fowl, flowing through practically unbroken forest. In fact, he was so entranced by it that he brought the whole family to settle on the banks.

Were my ancestor to return today, he could recognize only the river, so much have the surroundings changed. Nevertheless, the St. Clair is still a beautiful and vital stream, thanks to a good deal of hard work and the investment of very considerable sums of money.

Now were I to be transported to the same spot in the year 2,000, I am sure that I would find the changes of the next 33 years to have been even more drastic than those of the last 133. Studies currently being made for the Detroit Edison Company predict that in 2,000 A.D. Metropolitan Detroit will have a radius of 100 miles and that the Great Lakes megalopolis will encompass both shores of the lower lakes from Chicago to Montreal. Still I am confident that I would find the St. Clair to be a maginficent and living river.

One of the reasons for this confidence is the result of a poll of 100 major industrial firms with head offices in Ontario and Quebec which was conducted last summer by the National Research Council Associate Committee on Water Pollution Research. This showed strong support for a very high level of water quality to be maintained by effluent objectives based on the optimum use of the diluting and digesting capacity of the receiving stream and supervised by strong and able control agencies.

The answers to the poll also stressed that the problems in water pollution control, which were of greatest concern, involved economic, social and legal aspects which were at least as important and difficult as the technical phases. This larger involvement is particularly evident and of tremendous importance in the selection of water quality objectives, criteria or standards.

Two major and conflicting approaches to the problem are illustrated in Dr. A. E. Berry's "News from the Field" for May:

Mr. Murray Stein, Chief Enforcement Officer, U. S. Water Pollution Control Administration:

"We have to develop water quality standards covering a broad spectrum of substances and locations if we are to expect industries and municipalities to invest hundreds of millions of dollars in waste treatment facilities. They have a right to expect us to provide them with certainty that the standards are firm and right. In doing this, we must always give precedence to our obligation to the people that the standards are so

framed as to protect the maximum number of present and future water users".

Mr. E. J. Cleary, Executive Director and Chief Engineer, ORSANCO:

"In considering what the goal of pollution control is, we must ask - is it prohibition of discharge of any amount of any substance in any body of water, or is the objective the pursuit of quality management program for obtaining the greatest utility from the use of water? I would suggest that the latter goal - quality management - represents a realistic aim. One of the essential steps in developing a management program is the establishment of standards tailored to uses".

If it is assumed that population, industry, and agriculture continue to grow at something like the present rates, the water quality requirements of both systems ultimately will coincide. There are, however, very great differences in practicability and cost between the two approaches and it is essential that we choose wisely.

I feel very strongly that we should adopt the principle of water quality management because:

1. The problems of achieving control of effluent quality in large cities are now formidable and will increase as metropolis merges into megalopolis:

    (a) The attached table shows the average discharges from Detroit in 1963 as reported by United States Public Health Service. (1) At this time, Detroit had just spent $750,000,000 on the sewage system without achieving separation of storm and sanitary sewage or more than primary treatment.

    (b) The U.S.P.H.S. Conference at Cleveland last summer showed similar conditions in other cities discharging into Lake Erie. There have been suggestions that

$20,000,000,000 may be the price of control on the U.S.A. side of the Great Lakes.

(c) Senator Muskie has estimated that $20,000,000,000 will be required to raise U.S. municipal sewage treatment to minimal acceptable standards by 1972. This will rise to $100,000,000,000 by 2,000 A.D. if separation of storm and sanitary sewage is to be provided.

2. We do not know enough to establish ultimate standards of water quality:

   (a) We have been so busy "fire fighting" that we have not been able to estimate future control requirements on the basis of foreseeable loads. This is a particularly useful field for investigation.

   (b) Despite world wide research efforts, we do not yet know the causes and cures of such urgent problems as eutrophication.

3. We must provide time for the scientific and engineering community to discover and develop cheaper and more effective solutions to the outstanding technical problems.

4. Since the G.N.P. is the only source of funds for this tremendous task, it is as important to avoid unnecessary expenditures as it is to make the necessary ones.

An excellent summary of the present situation in the U.S.A. is contained in "Restoring the Quality of Our Environment" (2) which considers all aspects of environmental pollution. It states:

"Such standards imply that the community is willing to bear certain costs or to enforce these costs on others in order to maintain its surroundings at a given level of quality and utility. For each pollutant, the elements that must be taken into account

are: its effects, technological capabilities for its control, the costs of control, and the desired uses and resources that the pollutant may affect.

These complex problems cannot be handled without a sufficient number of trained technicians, engineers, economists, adminstrators, and scientists, and without the requisite scientific, technical, and economic knowledge. The manpower and knowledge now at hand are insufficient for the complete task, though much can be accomplished with our present resources".

Since these limitations are equally evident in Canada, it is suggested that our approach to establishing water quality control objectives should be based on:

1. Establishment of tentative control objectives applicable to individual watersheds, which take full advantage of the diluting and digesting capacity of our water and endeavour to attain the best possible benefit/cost ratio.

2. Revision of the objectives at five year intervals in the light of the best available information.

3. Forecasts of probable trends in control requirements in the individual regions should be prepared and maintained to minimize expensive mistakes in municipal and industrial planning.

REFERENCES

(1) Report on Pollution of the Detroit River, Michigan waters on Lake Erie and Their Tributaries.

U.S.P.H.S. - April, 1965

(2) "Restoring the Quality of Our Environment" - The Environmental Pollution Panel - President's Science Advisory Committee Government Printing Office - Washington, D.C.

AVERAGE DAILY DISCHARGE OF POLLUTANTS INTO

U.S. WATERS OF DETROIT RIVER

1963

		MUNICIPAL	INDUSTRIAL	TOTAL
TOTAL FLOW	T/D	270,000	550,000	820,000
5 DAY B. O. D.	T/D	251	125	376
SETTLEABLE SOLIDS	T/D	150	350	500
OIL	T/D	64	12	76
SOLUBLE PHOSPHATE	T/D	35	--	35
AMMONIA	T/D	17	4	21
CHLORIDES	T/D	250	1,000	1,250
PHENOLS	LB./D	1,200	1,400	2,600

CONTRIBUTION OF A. A. SCHULDT

Canada's largest single steel producer, The Steel Company of Canada, Limited, has its primary steel producing facilities located adjacent to what might be considered an unlimited quantity of water. I am referring to the Burlington Bay with its interconnection to Lake Ontario. Although it appears that the required water quantity for the operation of an integrated steel mill is available for just the cost of pumping and distributing, Stelco is very much concerned about the quality of available process water in the immediate vicinity of the plant. Substantial sums of money and engineering efforts have been spent to control and abate wastes which invariably result from the operation of such a steel complex.

In the making of iron and steel and in the refinement and shaping of steel, large quantities of water are required. About 220 million gallons of water per day, or 21,000 gallons of water per ton of steel produced, is circulated through the plant. Even though the water is used many times over before it is discharged to Burlington Bay, only a small percentage comes in contact with the product or pollutants. It is this portion of the process water which will require an active research program, operating modification and engineering pioneering to further improve further the quality of the discharged process water.

Having recognized some time agc the importance of waste control, Stelco's water management can be considered progressive and effective. To the long list of pollution abatement equipment that has been installed, another major installation has just been added with the official opening of the Hydrochloric Acid Regeneration Plant on June 14, 1966. This closed loop hydrochloric acid pickling operation has significantly reduced the acid and dissolved iron wastes from the plant. Because of the gratifying success with this new pickling method, the conversion of the two sulphuric acid pickling lines to hydrochloric acid is now being investigated. Other engineering studies are attempting to develop methods of reducing the emissions of cyanides, phenols, suspended solids and oils.

To control the loss of coke plant organics, a closed water recirculation system has been put into operation a short time ago. In addition, a closed water system for coke quenching operation is included with the coke oven expansion program. The combination of these two improvements should result in an important reduction of suspended solids, organic wastes and biological oxygen demand in the coke oven area.

The removal of cyanide traces, however, which originate from the blast furnace process presents a very serious technical problem because of the large quantities of water which must be treated. Chemical treatment for such a volume of water for small quantities of cyanide is not practical with the present treatment methods available. The Mellon Institute is now researching this problem under the auspices of the American Iron & Steel Institute. Again, the only possible solution for cyanide elimination in the sewered process water could be recirculation.

In an attempt to upgrade the effectiveness of our existing lagoons, a two-pronged program has been initiated. The first stage involves the separation of spent clean cooling water from contaminated process streams. A major clean discharge sewer will be completed later this year and will relieve the lagoon system of 2.3 million gallons per hour. Synchronized with this schedule, automatic oil skimmers are proposed to intercept floatable oils. Again, these changes, coupled with our continuing program of new scale pits, (two were installed in 1965 and one in 1966) should manifest themselves in a lower discharge of suspended solids and oils.

This is only a partial list of accomplishments which have progressively reduced the waste load and brought the discharge concentration closer to the objectives set by the Ontario Water Resources Commission. Some ground still has to be covered to achieve all of the objectives and in some cases, such as cyanides and phenols, the objectives can only be achieved with a combination of recirculation and treatment of any bleed streams that might be necessary. Treatment technology has not yet solved the problem of purifying process water economically in the quantities required in basic

steelmaking. It must be recognized that all the waters cannot be restored to pristine purity. Lesser degrees of cleanliness are adequate for many uses as long as sufficient water is available and provided the health, welfare and prosperity of the nation is never endangered.

It may be that, in some quarters, because pollution control systems have been considered a costly and possibly an unnecessary evil, there has been some resistance to compliance with government objectives. For a number of years we have given prime consideration to effective pollution control as an integral part of basic construction planning. In the development of pollution control facilities, the industry is working closely with various governmental agencies and authorities in a spirit of co-operation, support and willing compliance. Given time to space out large expenditures over an economically feasible period, we are confident that the remaining problems can and will be solved.

CONTRIBUTION OF R. H. MILLEST

Basic water pollution control legislation is almost universally clearly prohibitive to ensure that the highest order of water quality can be maintained wherever necessary. Impairment of any kind is prohibited, and, in this strict interpretation, is an adjunct to the long-established common law that ensures riparian owners the continued use and enjoyment of an uninterrupted flow of water of unimpaired quality.

But is is evident that the expanding use and re-use of water in the modern industrial society leads to impairment of one kind or another, in the sense that certain changes in the quality of water inevitably occur, and, while these changes may not necessarily restrict the downstream use of water, they nevertheless give rise to the practical need for the use of some degree of discretion in the interpretation of the legislation. When this is done, some means of gauging water quality impairment (or more properly, of defining the state of unimpaired water) is required. I gather from reading the proceedings of cases that have gone to the

courts that many issues were decided by judicial opinion only, although the professional opinion of public health or other qualified persons generally formed the basis for determination. While much still rests on opinion, the principle of applying an accepted schedule of objectives, or other yardsticks, to water pollution control has now become well established.

Recognizing the need for still providing for the complete prohibition of water quality impairment, and at the same time providing for discretionary power on the administration of water resources, the legislation of Ontario included in the OWRC Act the provision for the enactment of regulations for (among other things):

"47 (f) - regulating and controlling the content of sewage entering sewage works,

(g) - prescribing standards of quality for potable and other water supplies, sewage and industrial waste effluent, receiving streams and water courses,

(l) - regulations... respecting any matter necessary or advisable to carry out effectively the intent and purpose of the Act."

Thus, the Commission from the outset had the authority to establish schedules of controls in any one of several ways. However, bearing in mind the size of the Province and the difficulty to be encountered in applying rules that would be applicable to all waters, the lack of a completely satisfactory and reliable schedule of limits at the time the OWRC was established led to the decision to adopt a schedule of Objectives, rather than regulations, that, in effect, defined the requirements for clean water, regardless of location or water-use. On the basis of these, then, it was, and still is, the aim of the Commission that all waters in Ontario be returned to or retained in a "clean state" and that no waters be considered as irrecoverable. The Objectives for Industrial Waste Control that were adopted last year

were intended to complement the general Objectives for Water Quality by setting out effluent objectives that would, in general, satisfy the receiving water requirements.

I am sure that there will be questions raised in the discussion to follow regarding the choice of certain of the Objectives, but I think it should be borne in mind that they represent an aim or goal toward which to work and that they should be attained if it is technically and economically feasible to do so. In many cases they will represent an ideal condition that is difficult, if not impossible, to attain economically, and in such cases there must then be a rational interpretation of the water quality needs and interests to be served.

The Objectives have been considered to be well suited to the needs in Ontario where the program of achieving pollution control up to this time has been largely by persuasive methods and cooperative action. It may well be that the program has evolved to the point where either a major revision to the Objectives should now be considered or where other means of control should be scheduled as provided for in the OWRC Act. Whatever the choice it should be expected that the requirements will be tightened as water-use continues to intensify. If specific regulatory limits are to be used, it can be expected that there may be a loss of flexibility, since the rules become hard and fast when set out under specific statutory authority. The use of discretion almost necessarily then gives way to arbitrary determination. We cannot set our sights only on what we have been able to accomplish in the past, or are able to do at the present time - we must look to what we think we are going to need in future water use.

In summary, then, Objectives can serve as a means toward an end in a period of development or evolution of reliable and acceptable pollution control regulations. They permit a degree of flexibility that is needed in the "case by case" approach to pollution control and when a decision to introduce more rigid requirements must be taken they will have served as the basis for an orderly transition.

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